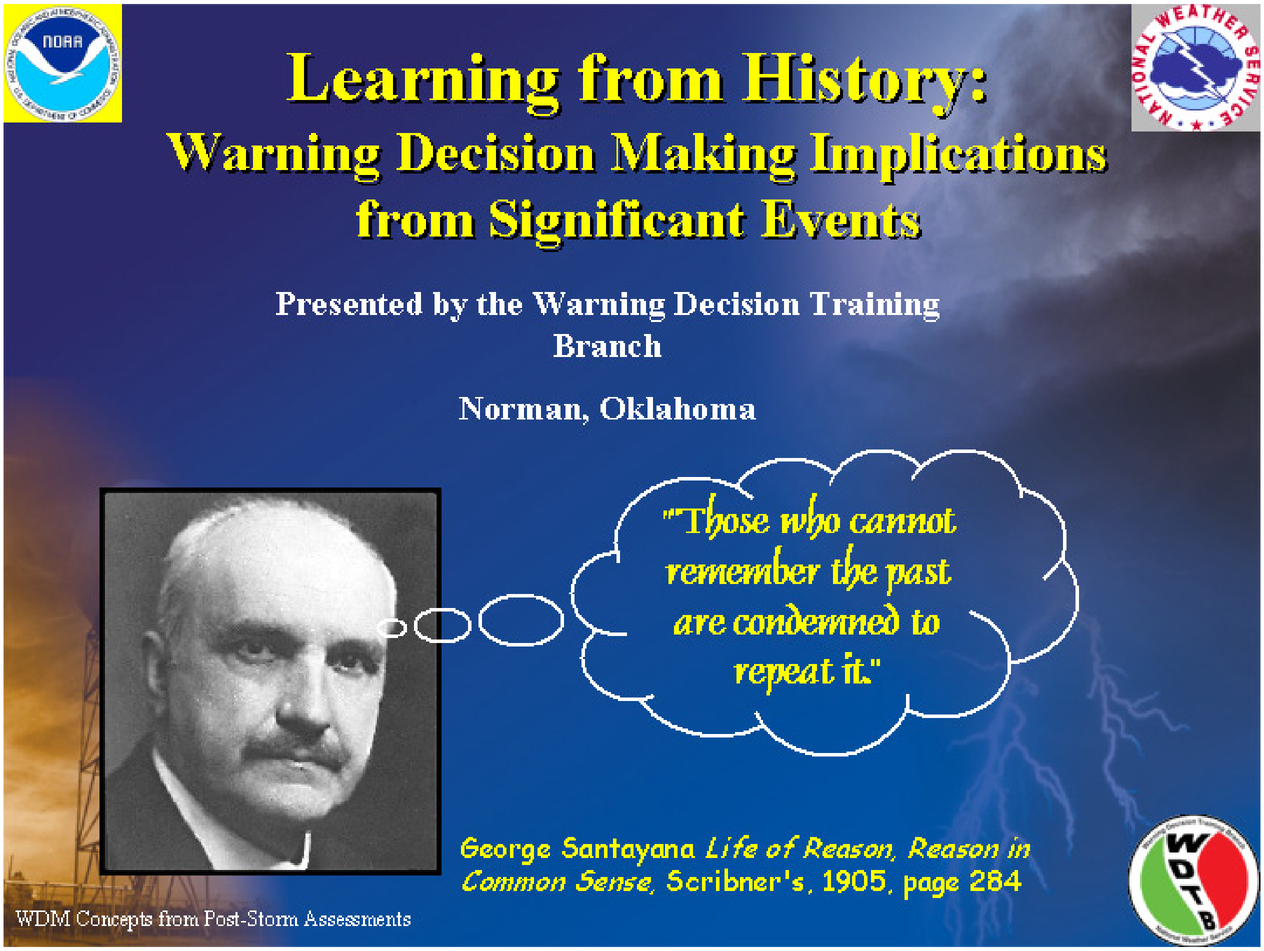
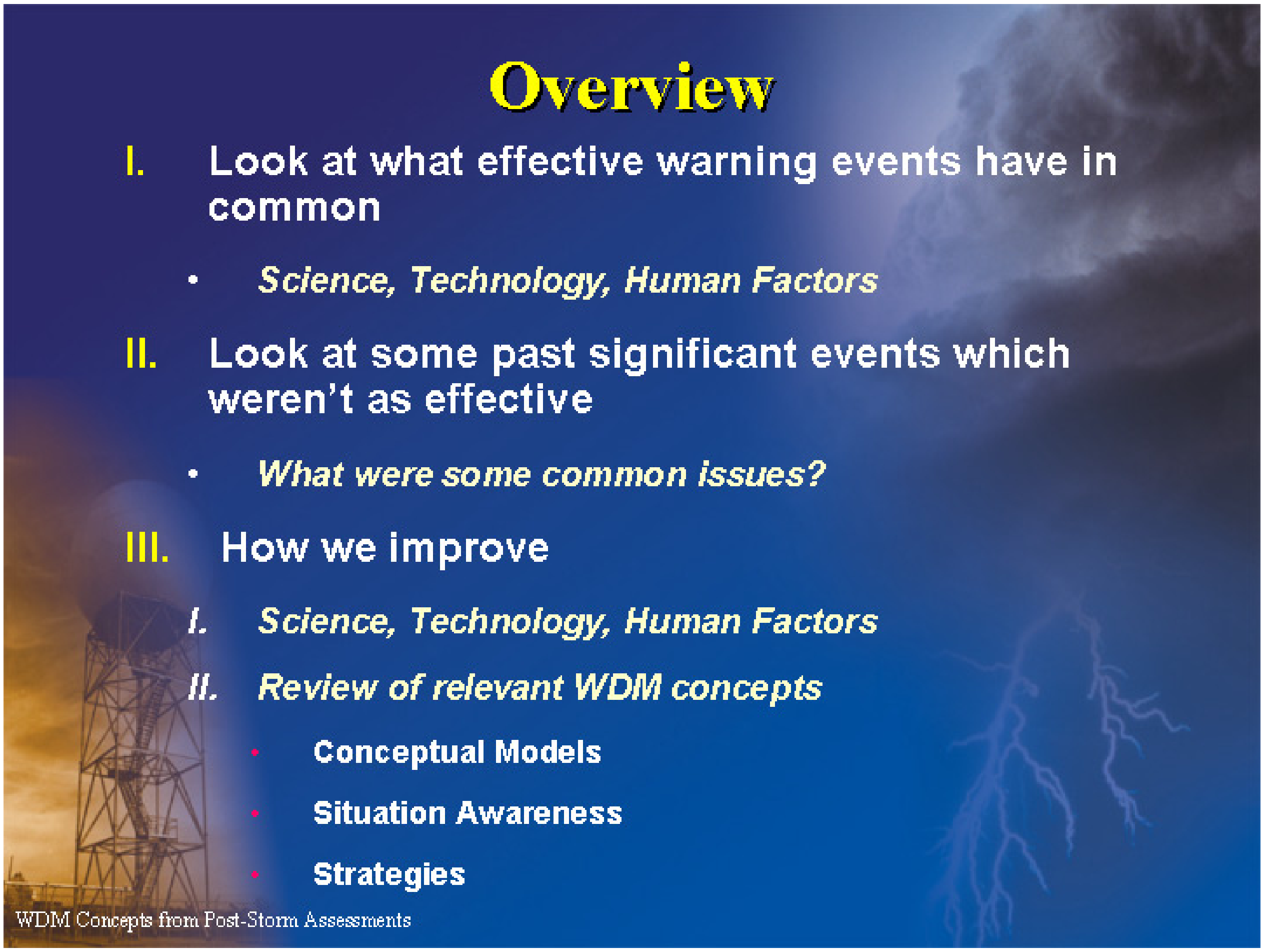
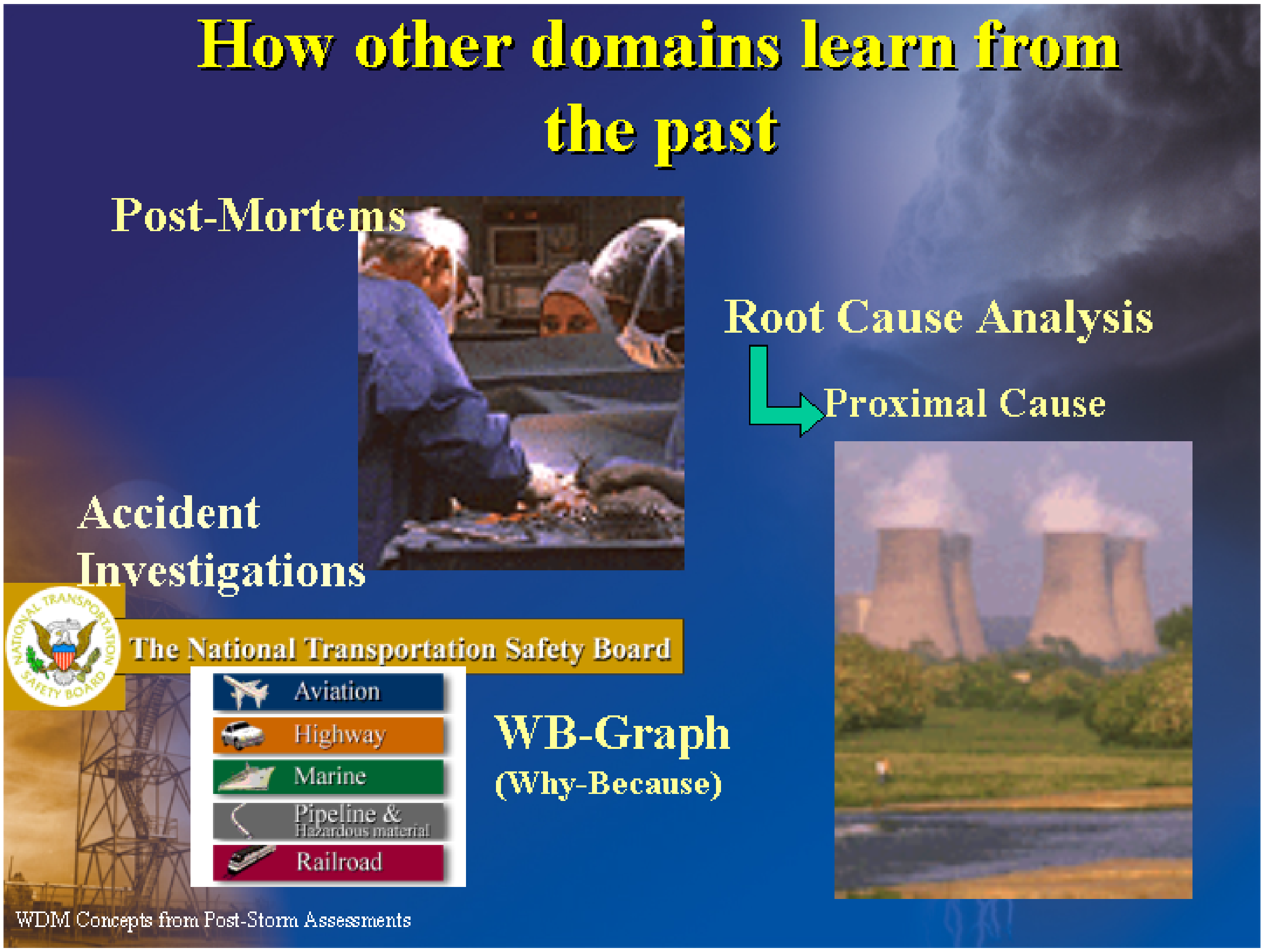


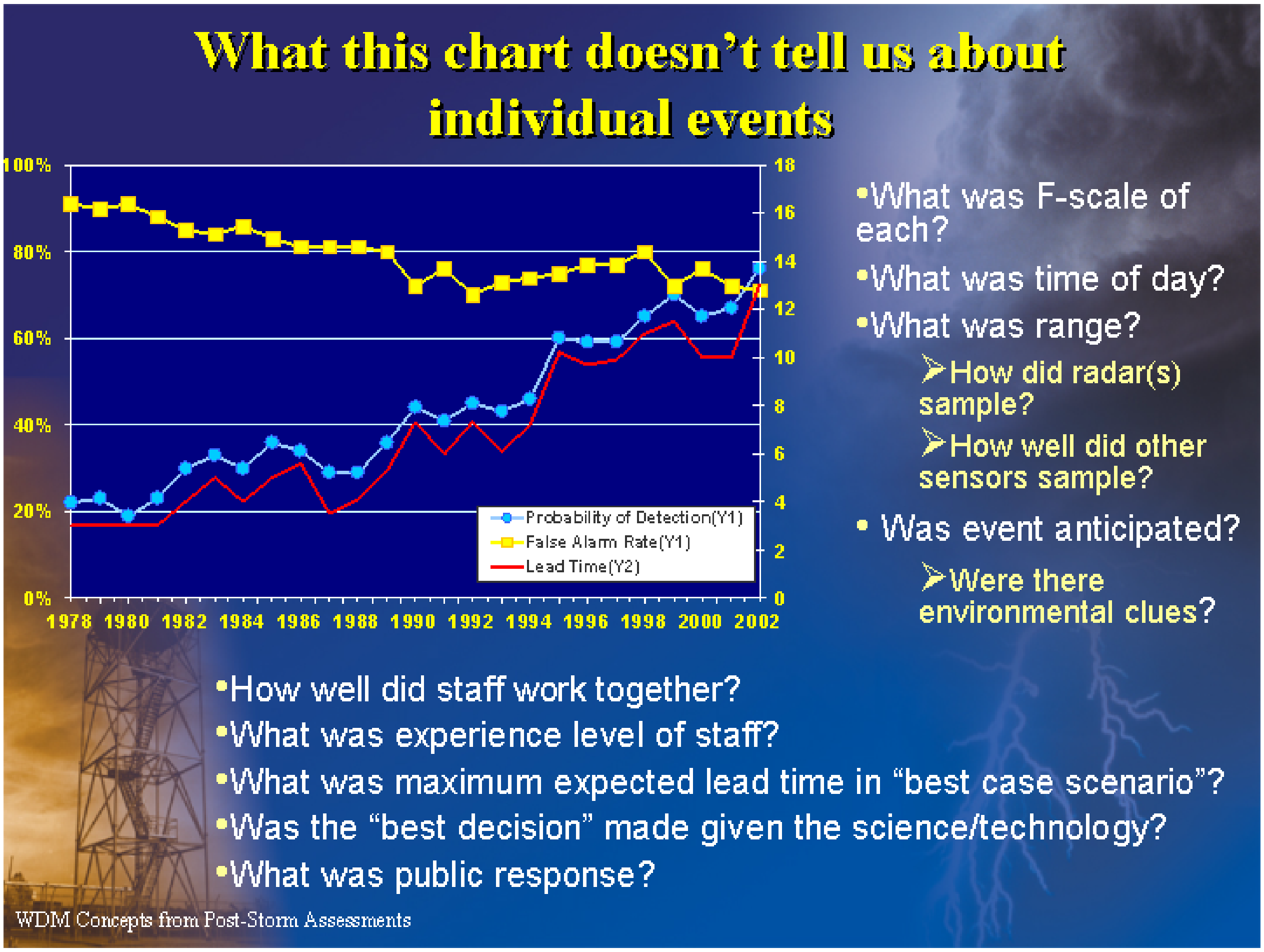
I would like to welcome you to this recorded VisitVview session entitled "Learning from History: Warning Decision Making Implications from Significant Events." It is being presented today by the Warning Decision Training Branch in Norman, Oklahoma. My name is Liz Quoetone and I will be co-presenting this session with Jim LaDue. The session deals with a summary of warning decision making concepts as they apply to significant tornadic weather events in recent history. The session runs about an hour and a half long, you are welcome to stop and start anywhere along the way. I would like to start with this quote that I think probably most of you are very familiar with from George Santiana, "Those who cannot remember the past, are condemned to repeat it." And we certainly want to take a look at our past and see what we have done well and see what we have not done so well and learn from that and make changes in the future.



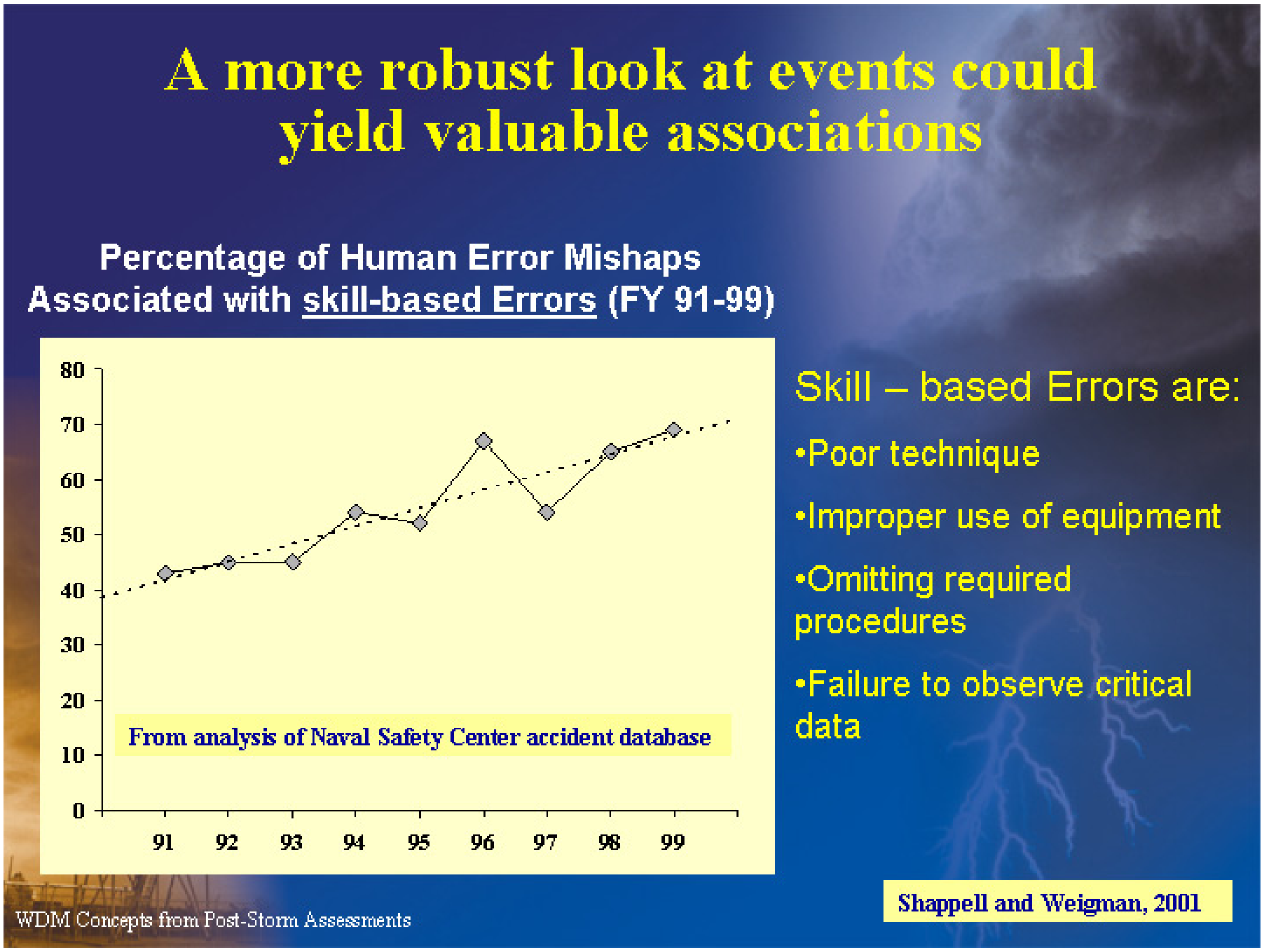
To kind of give you an overview of what we will be talking about during this presentation; one of things we will do is look at what effective warning events have in common, and those are things we want to try to emulate, not always just looking at things that don't go well but things that do go well. We will break this down into three areas: the science contribution, the technology contribution, and the human factors contribution and you will see this theme kind of repeat itself throughout this presentation with these three categories. So we will look at what these things look like in an effective event. Then we will look at some past significant, in this case, I am going to be dealing with tornado events, which perhaps weren't as effective. We will look at twelve significant tornado events over the past many years and find out what were some things which recurred or were brought as issues in each of these events. And finally we will look at what do we do with that information, how do we improve. Well, there are things that we can do with the science, technology, and human factors, which will result in some improvements. One of the things we will do right here in this presentation is provide a review of relevant warning decision making concepts, those concepts from Warning Decision Making Workshops which many of you may already have in place at your offices. But in particular, a review of conceptual models, as conceptual models will be an issue from time to time during these significant events, a review of the what the term situation awareness means and how is applied, and what it looks like in a warning environment. Finally, some office strategy, how we run things in an event in order to make the best use of our resources. Those of you who are familiar with all of these three aspects, may breeze through that section pretty fast. But if you haven't been exposed to it, you may want to take some time and look at some of these concepts and as well as share then with others on your staff.



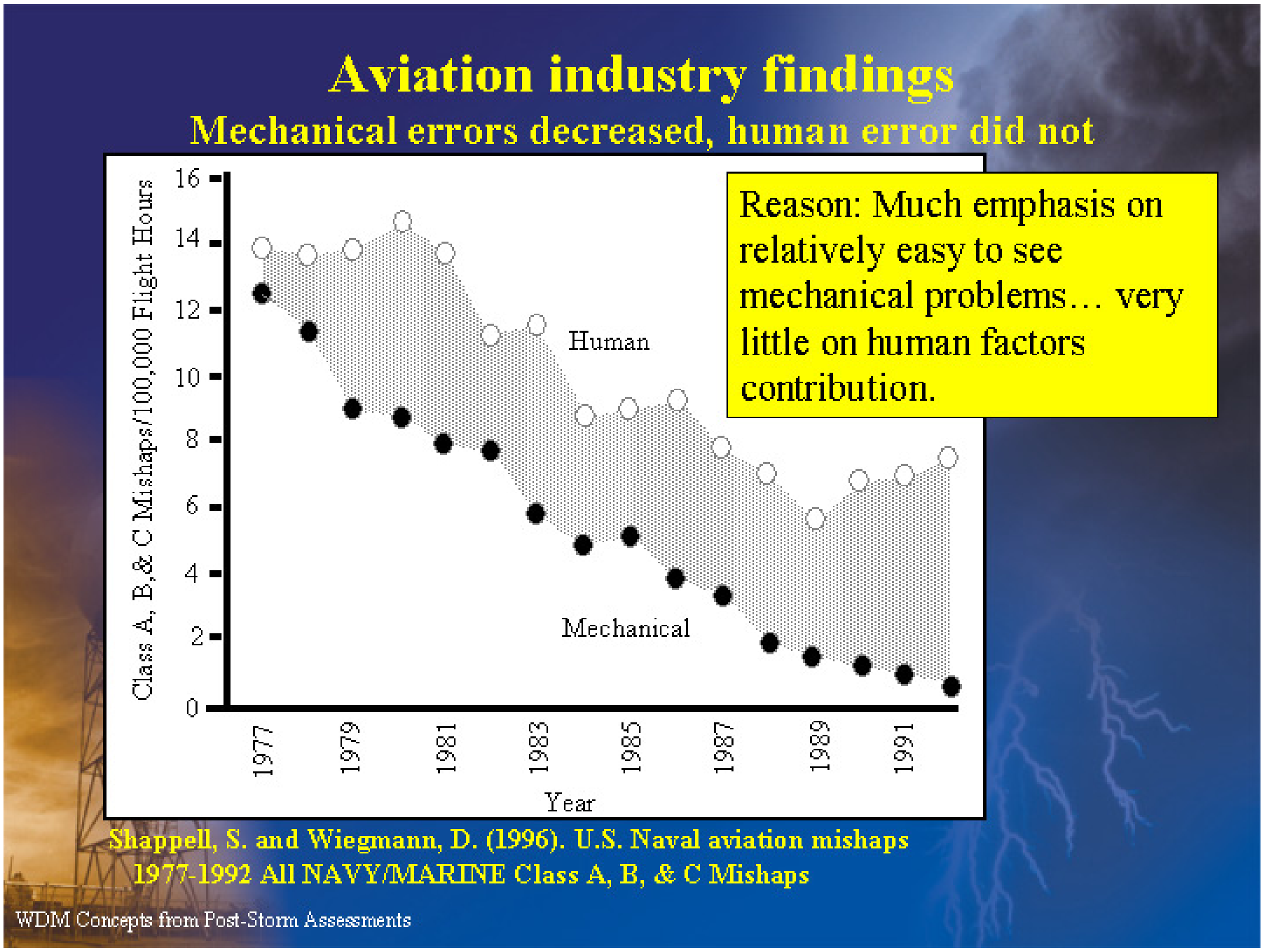
Ok, looking at what we've done in the past is certainly not a new concept. Other domains have been doing that for many years and we do that in the Weather Service and you do that in your office to some degree probably, as well. In the medical field, there is the post-mortem, which looks at why things happened the way they did or what led to the ultimate outcome. Root cause analysis is a tool that is used to find what factors contributed to an outcome. The term root cause may imply that there is one single cause but as it turns out you really have branches upon branches of contributors when you do a root cause analysis. Some of the most famous investigations are done by the NTSB which does a fairly thorough look at the events or incidents and what led to them. So there is precedence for doing this type of thing and certainly you can gain a lot of information from what is revealed by looking at the past.



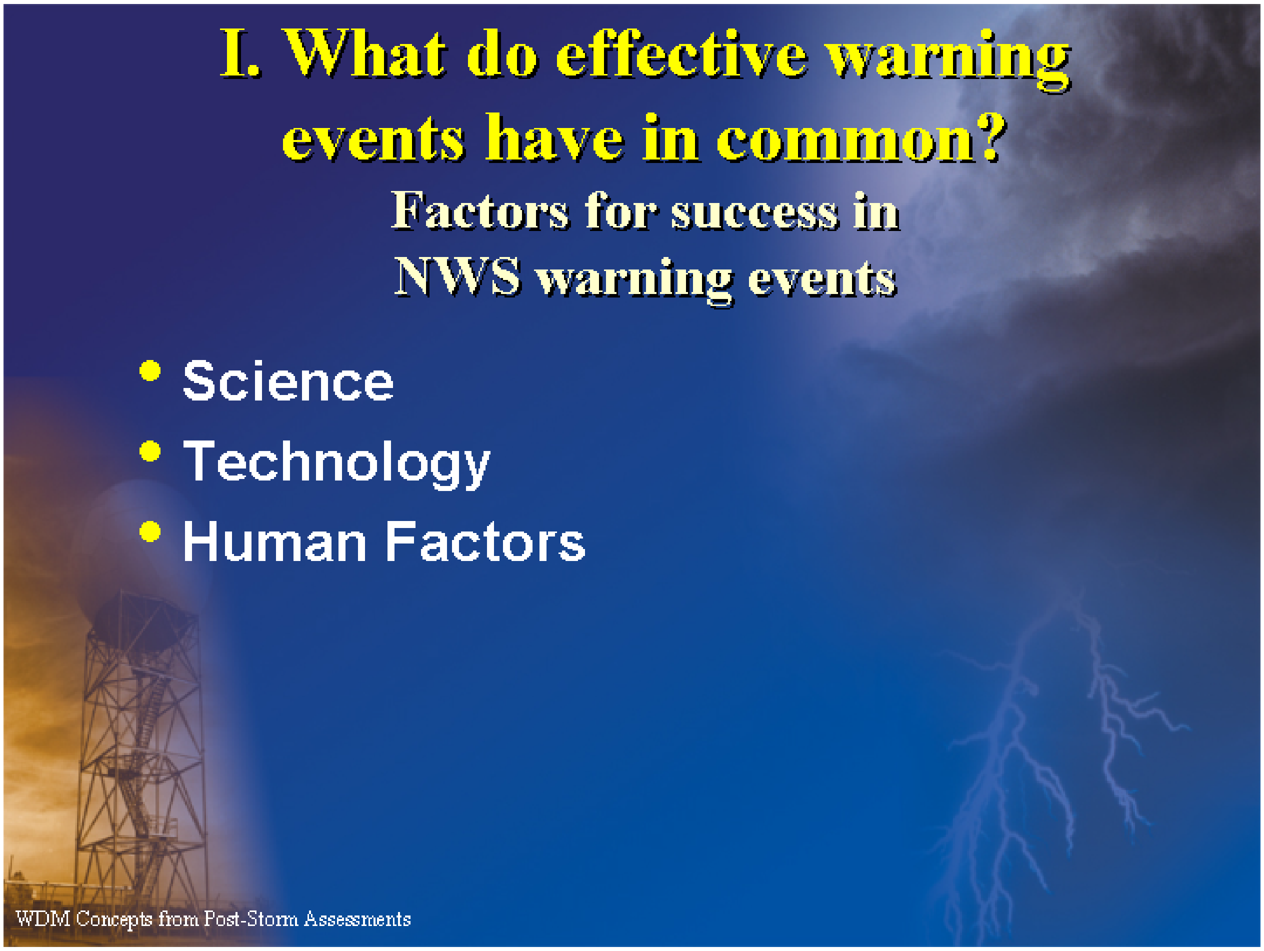
This type of chart is probably pretty familiar to most of you. We do calculate statistics measuring certain aspects of our performance. In this case, we have a chart indicating probability of detection, false alarm rate, lead-time over the years for tornadic events and that gives us some information. What this particular type of chart won't tell us is things like what was the F scale of each of these tornadoes, what was the range, how well did the radar and other sensors sample the environment and the feature in question. Was it something we anticipated, or did it kind of catch us by surprise. What was the best we could do, the best lead-time we could have gotten and did we make the best decision given the science and technology. These types of things require a further look, a deeper look at what was going on during the time of the event.



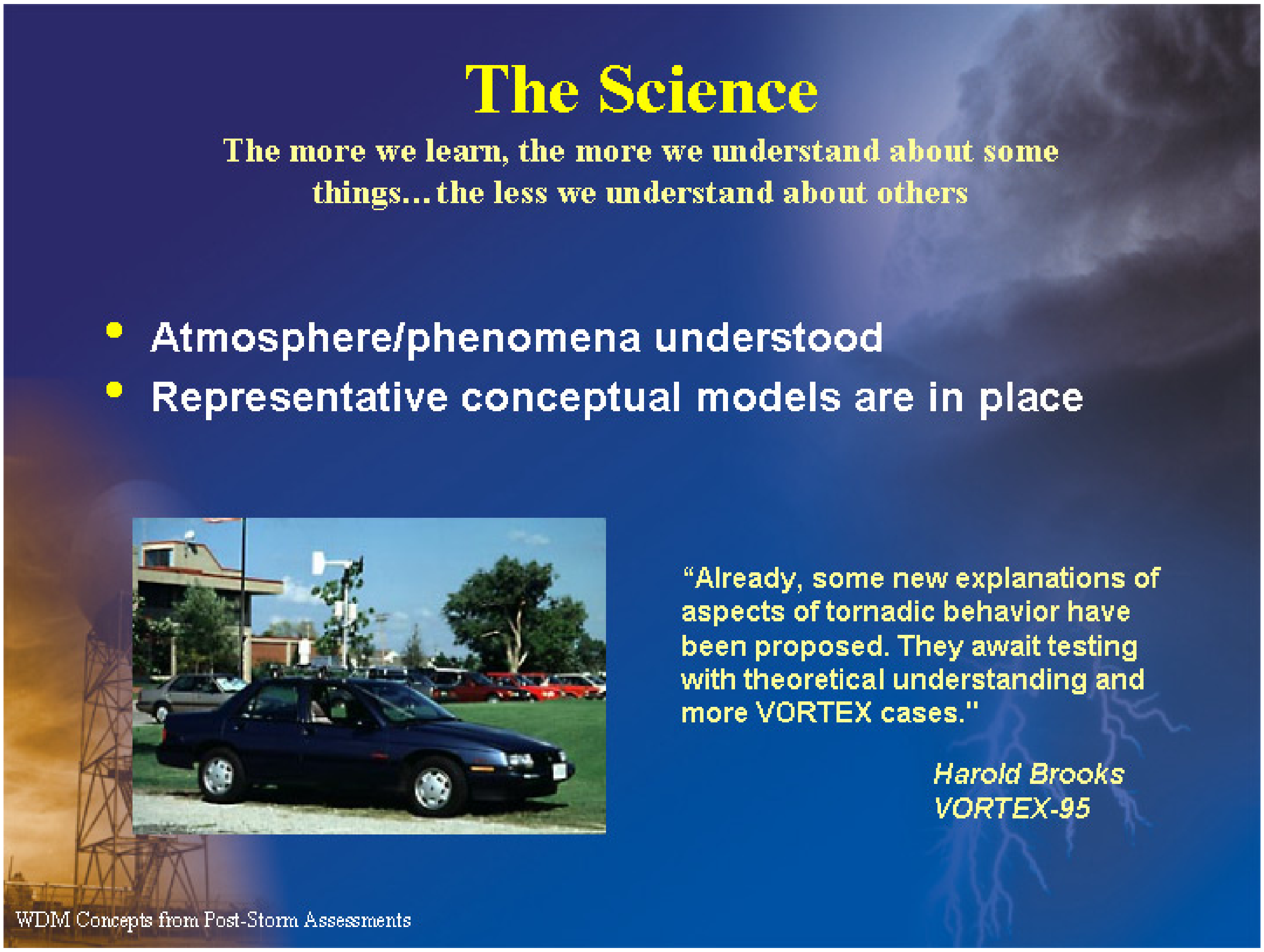
I wanted to give you an example of what type of information can be gleaned by a very robust look at events in questions. In this particular example, this is from a database that the naval safety center has put together based on incidents that they have looked at over the years and the types of information that they gather about the events in question. For instance, they have a category called skilled based errors, and for each incident they look at the type of things that perhaps would indicate a poor technique, equipment not being used properly, omitting procedures, not looking at critical data, very detailed look at not just the facts of the incident or accident in their case but the context and the environment in which these things occurred. And so for them using that kind of a robust database, they can see that for example these types of errors are increasing through time, skilled-based errors and that is some important information. But it takes a good look at the time of each event so you can save this type of information in order to see this type of trends.



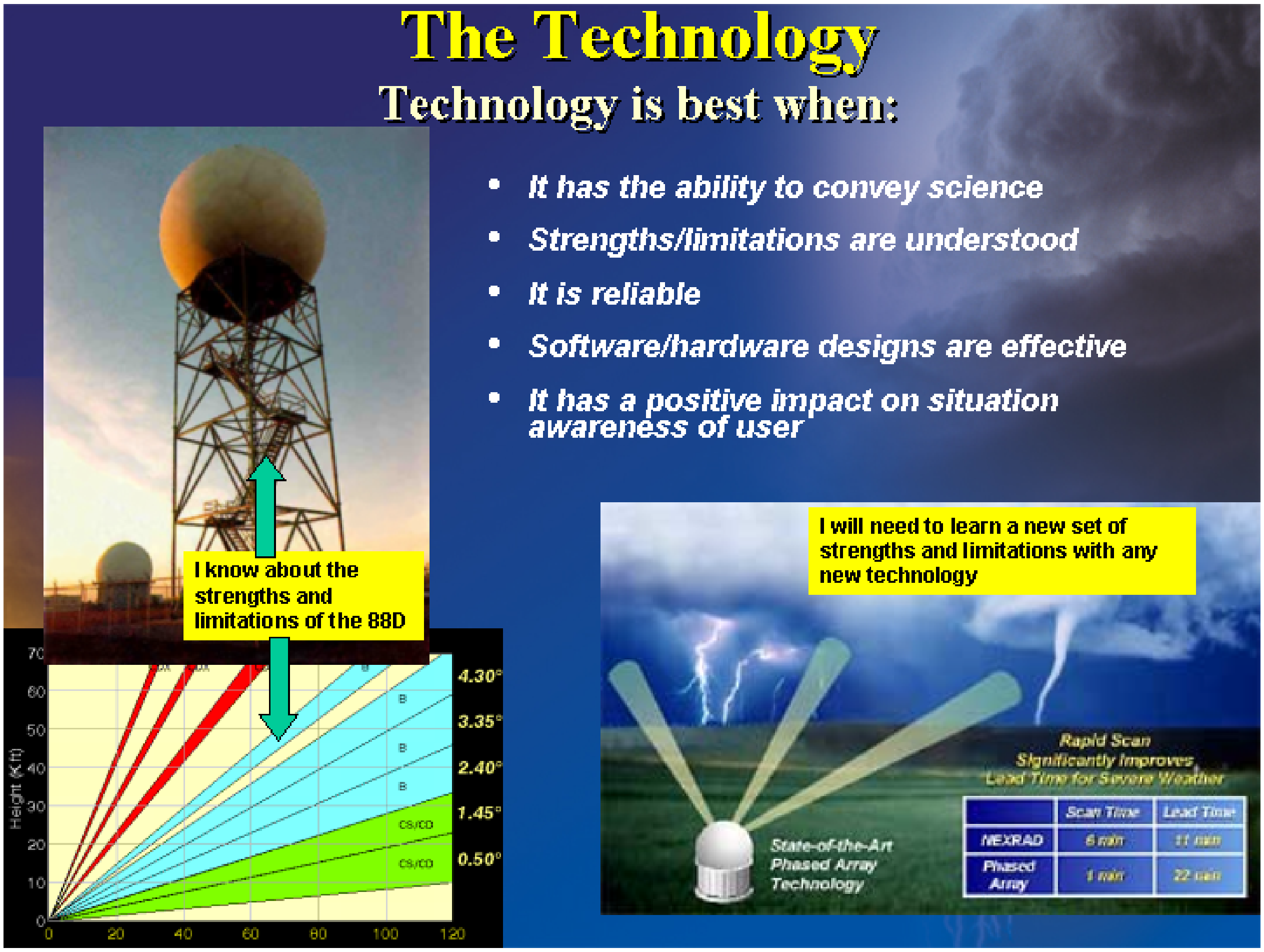
In looking at how the aviation industry has done over the last few years, we can see that through time the mechanical errors which seem to be occurring as a cause or contributor have been decreasing. We look on the other hand at the human contributions, and that would include human and technology interaction, we can see that there is actually a trend toward the end here that those types of errors are increasing. And it could be that we have put so much emphasis on mechanical problems which are fairly easy to find and isolate and therefore adjust before there is another incident and not as much time on the human contribution and the human-technology interaction. And if you don't isolate those then how can you do some intervention to prevent them in the future.



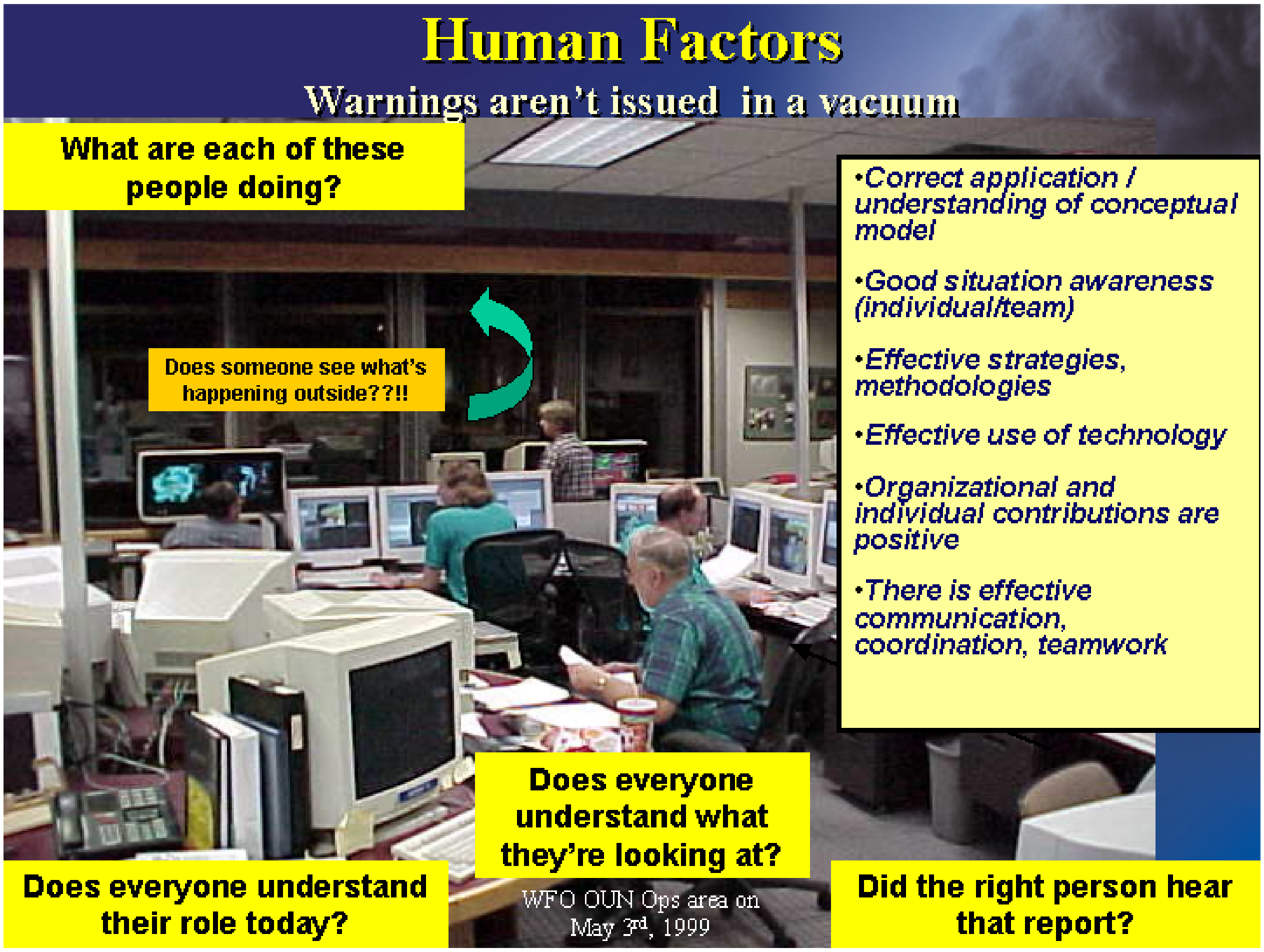
So trying to take a more robust look at these events that we chose, we want to look at the science, technology and the human factors contributions. First off, we want to know really what are the things we expect out of these three factors. What makes for success in warning events from science, technology and from human factors.



So what do we want from the science contribution to the warning event? Well we ultimately would like it to be some event which unfolds in a way that we understand and that is familiar, phenomenon is understood and we can apply conceptual model to it. However in some cases, in probably most cases, the more research we do, the more complex some aspects get and the ability to measure those aspects and quantify them can even be more difficult. Some of the findings from Vortex back in 95 reveal that perhaps all that we understood about tornadic behavior, tornadic development, isn't as clear-cut as we once thought. And so it tends to get more complex before it begins to get more clear, ultimately then giving us something we can apply. But what we want from science, is something that defines what is going on that we can apply in real time.

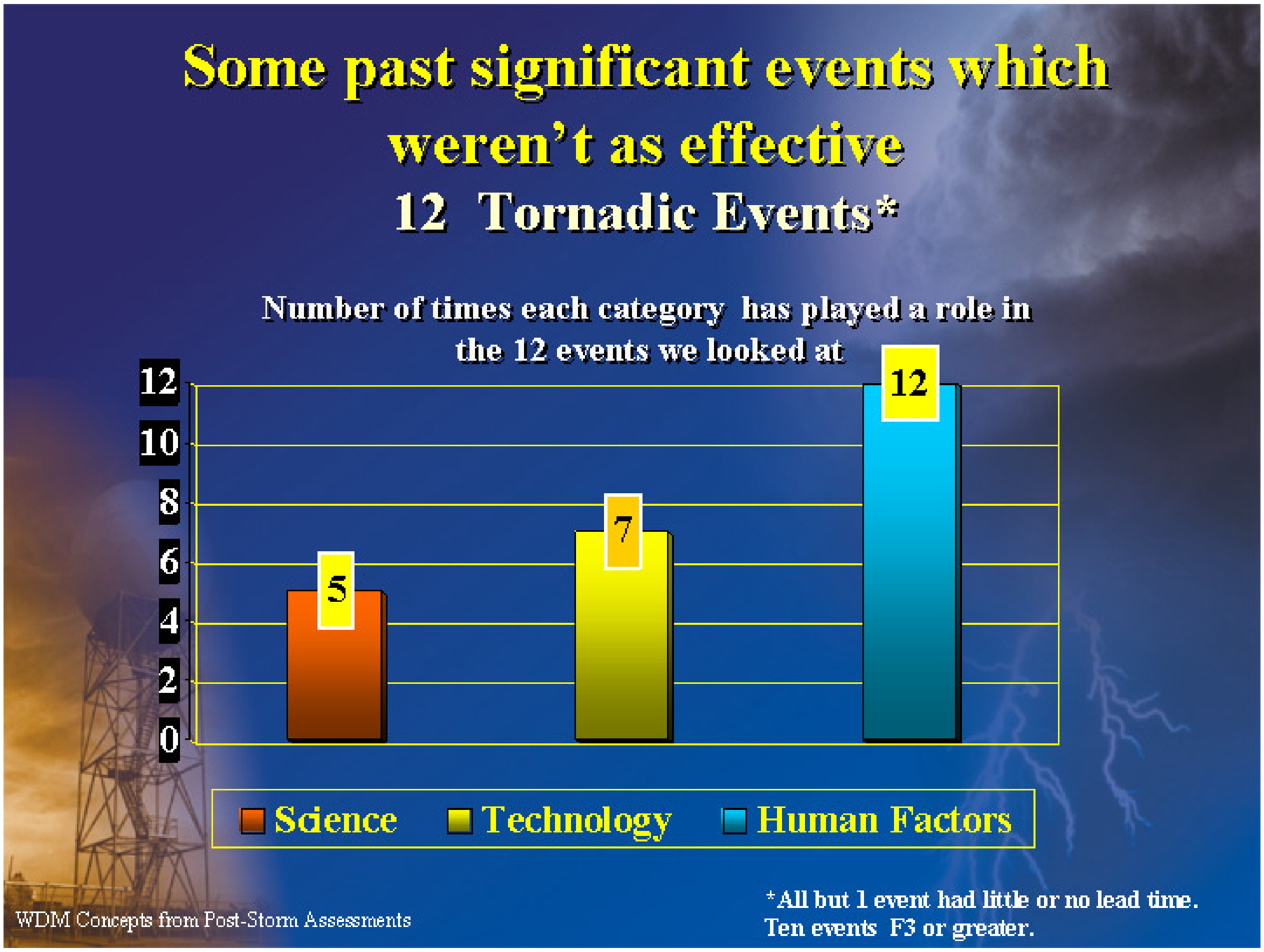


So what do we need from the technology? Well technology is at its best when it can convey the science that we understand. When we understand it, when we know its strengths and limitations, when it is something we can count on, when the designs are effective and easy to apply in real time. And it impacts our situation awareness, something we will talk a little bit more later but it basically gives us a good idea what is happening. And as the technology changes, so will all of these factors. For instance, the 88D has now been out in the field some 12 – 13 years in some cases, and most people have a fair amount of experience with it. They understand the strengths and limitations of the radar, at least we have been taught that, and most of us have experienced that and we understand then when it's likely not to give us the best picture of what is going on. With any new technology that comes around, whether it is the Phase Array or whatever it might be in the future we will need to learn a new set of strength and limitations and how learn how to apply that to the best outcome.

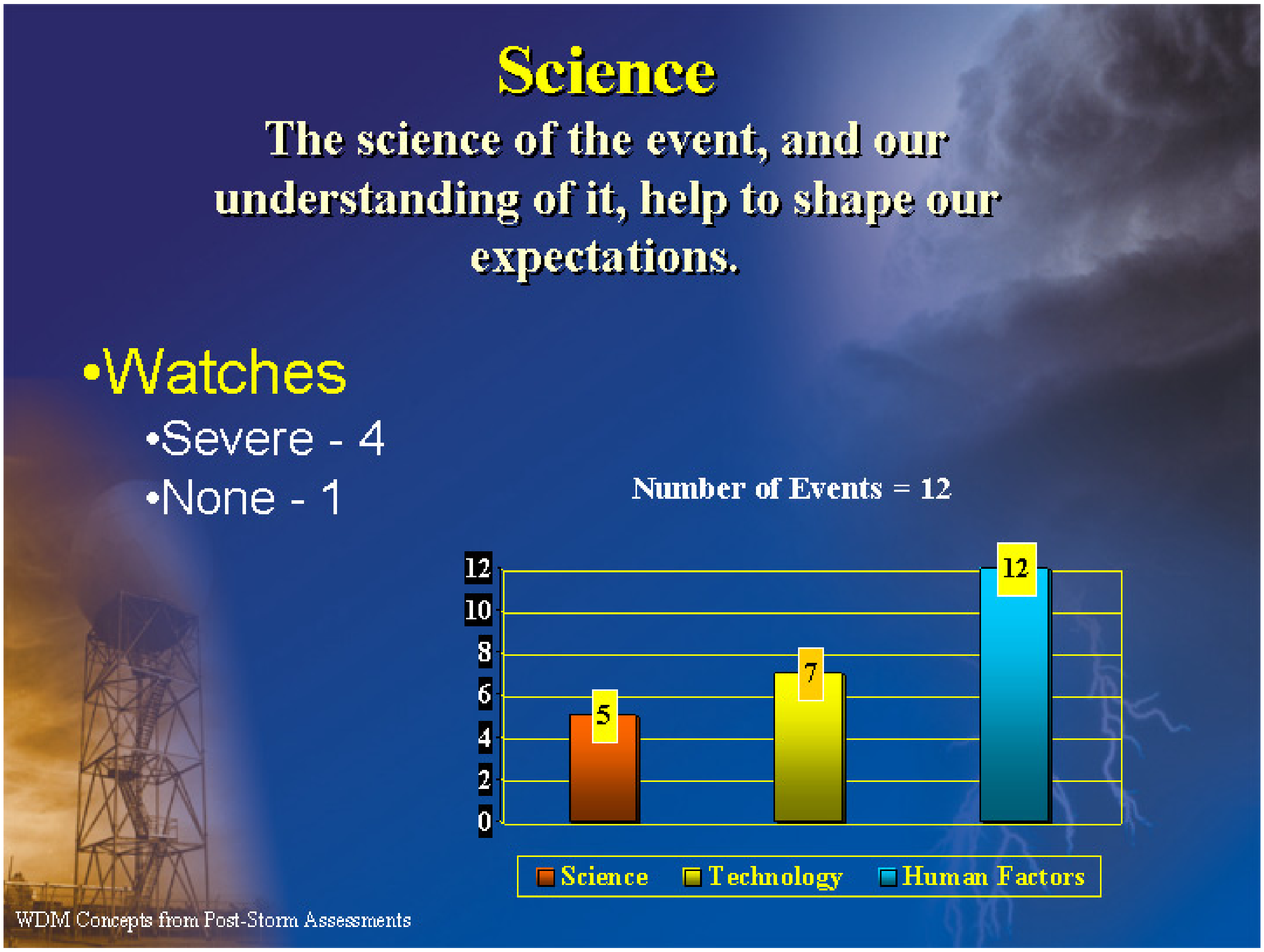


Ultimately it is going to be humans making these decisions, you, and me and everyone else will be taking all the technology and the science and putting it together to make a decision and we don't have the luxury of doing that in a vacuum. We don't have all day and we don't have the ability to call in experts at our whim to help us with interpretation and understanding of complex situation. We have to take what we know of conceptual models and hopefully recognize it in real time and apply it. We have to maintain good situation awareness, keep the big picture perspective flowing. We have to have some sort of strategy and methodology to wade though all the data, to configure our systems, somehow that we get the best picture and that requires an effective use of our technology. There are organizational as well as indivual contributions that are important, what you bring to the table, the training that you have, the experience that you have, the organization itself, what is the philosophy, how are things running with that organization. And all of this is in the context of effective communication and coordination as well as teamwork not with just the people working that event, but adjacent offices and partners. If you look at this photograph, it is an image taken of the Norman Forecast Office during the May 3rd tornadic outbreak. And it brings to mind several questions, you have lots of people doing various things, do they all know what their role is before they sat down, does their role change during the event, if so are they up to going with that change. This person right here just got a report, its a very significant report and he has to give it to the person whose warning responsibility covers that report, is it this guy or is it this guy. Are they hearing that report and incorporating it into their statements or warnings. And, oh by the way, did you look out the window and see the power flashes indicating that there probably was confirmation of a tornado going by. So lots of things happening and it is a context that can be very important to get right to make sure you are able to apply the science and technology correctly.

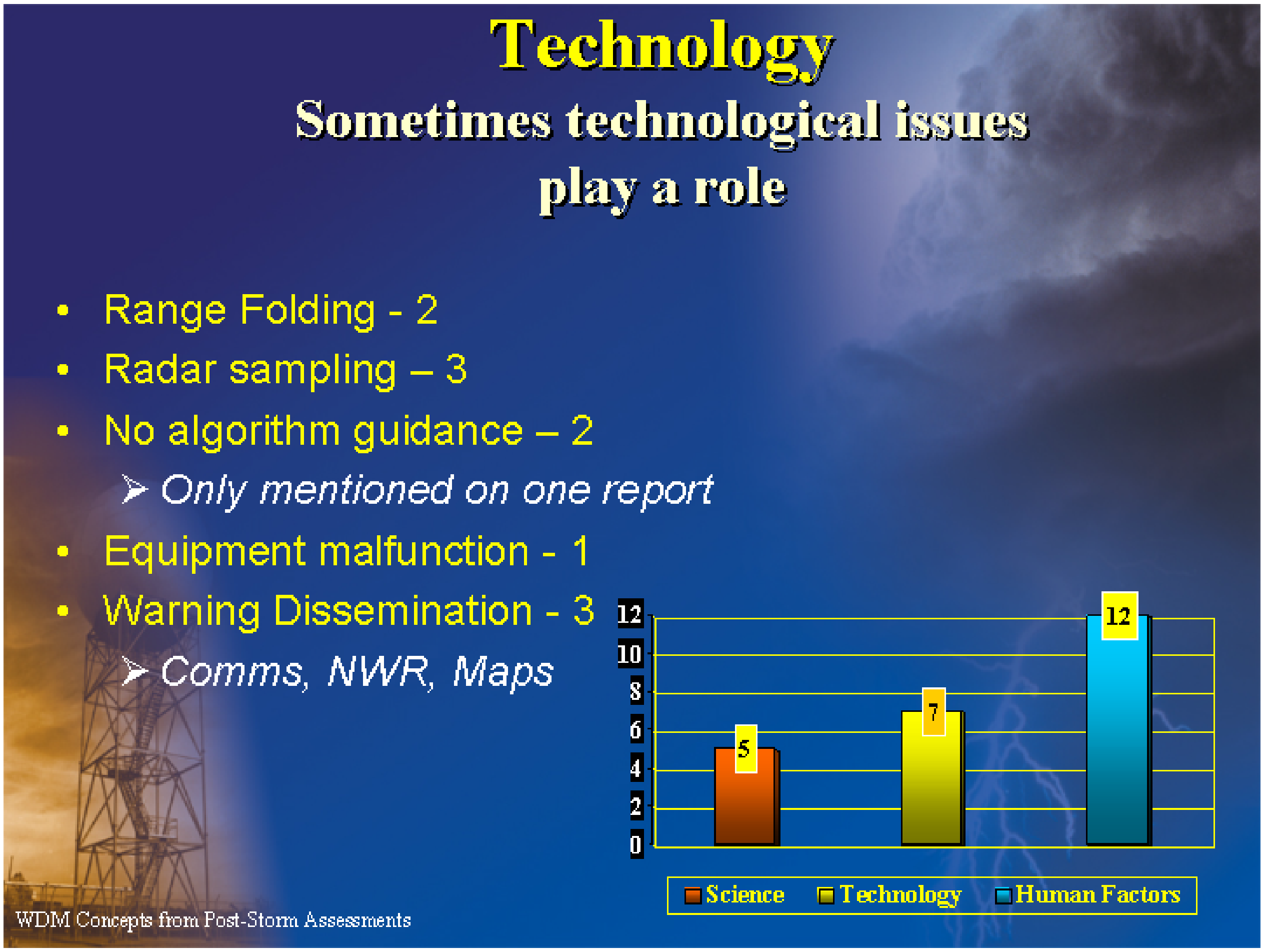
So we've looked at what we want from science, technology, and human factors for things to go the best that they can. What I want to do now, in this section, is look at some significant events from the past and we have got twelve events that we kind of culminated for this section, and look at what was going on with the science of these events, the technology of these events and the human factors, at least as best we can analyze from the data we collect during these events. What I will show you is a summary of those events, but I want to show you what one individual one might look like. For one particular event, in this case, we represented the science by whether or not there was a severe thunderstorm watch out, or tornado watch, or perhaps no watch, and what the risk was. So this tornadic event occurred with a severe thunderstorm watch box out and a moderate risk. That tells us a little bit about expectations, understanding of the science, a very simplistic representation of that, but it is something that we can at least get an idea of for this type of analysis. The technology on this day, well, everything pretty much went okay, except there were some inaccuracies on the map backgrounds which may have caused some challenges, certainly would for someone trying to do warnings. The human factors contribution on this day, this was a tornadic supercell, and it fit a conceptual model for a tornadic supercell and that was something hard to recognize in real time or it might not have been understood. But looking at all the information after the fact, probably most people would understand that to be fitting a conceptual model of tornadic supercell. So, we would have to look at why it was something that perhaps wasn't caught in real time. Situation awareness was an issue and that can be affected by inability to get real time reports and maybe that is affected by visibility and comms. Procedures were an issue, office procedures, strategies, the techniques used to interrogate storms were a problem on this day. There were problems with communication and coordination, but internally and externally; the roles and responsibilities were not clearly defined or were not clearly applied during the day. There were some issues with the ways things were worded and the relationship with the customer, meaning that perhaps, it was not so easy to communicate information, didn't understand each other's missions, etc, but there were challenges there. So these were contributors or things that were in place during this event which had a negative outcome.



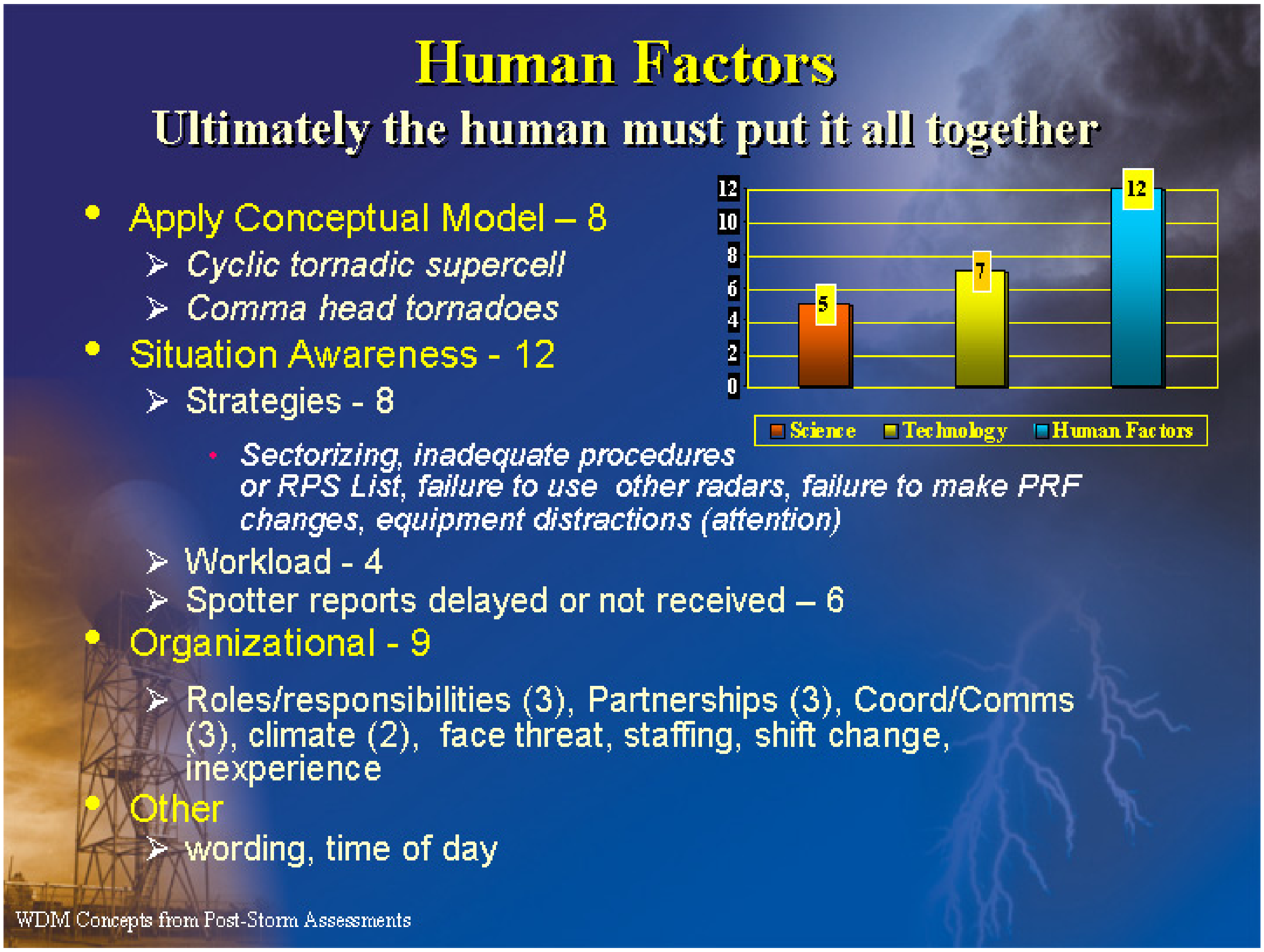
So looking at events in that fashion, we've got twelve of them. And these were tornadic events that I will tell you, ten of the twelve had tornadoes which were F3 or greater, and these are ones that we would like to believe we do a pretty good job with and most cases we do. But for these reasons, we didn't in these, all but one event had little or no lead-time. So of the twelve events, in five of them, there were issues with science, at least, perhaps by the organization or by the individual in question. In seven of them, there were challenges with the technology as contributors. And in all twelve events, perhaps, not surprisingly, there were human factors issues and we will look each of these things that showed up in these assessments and see what they were.



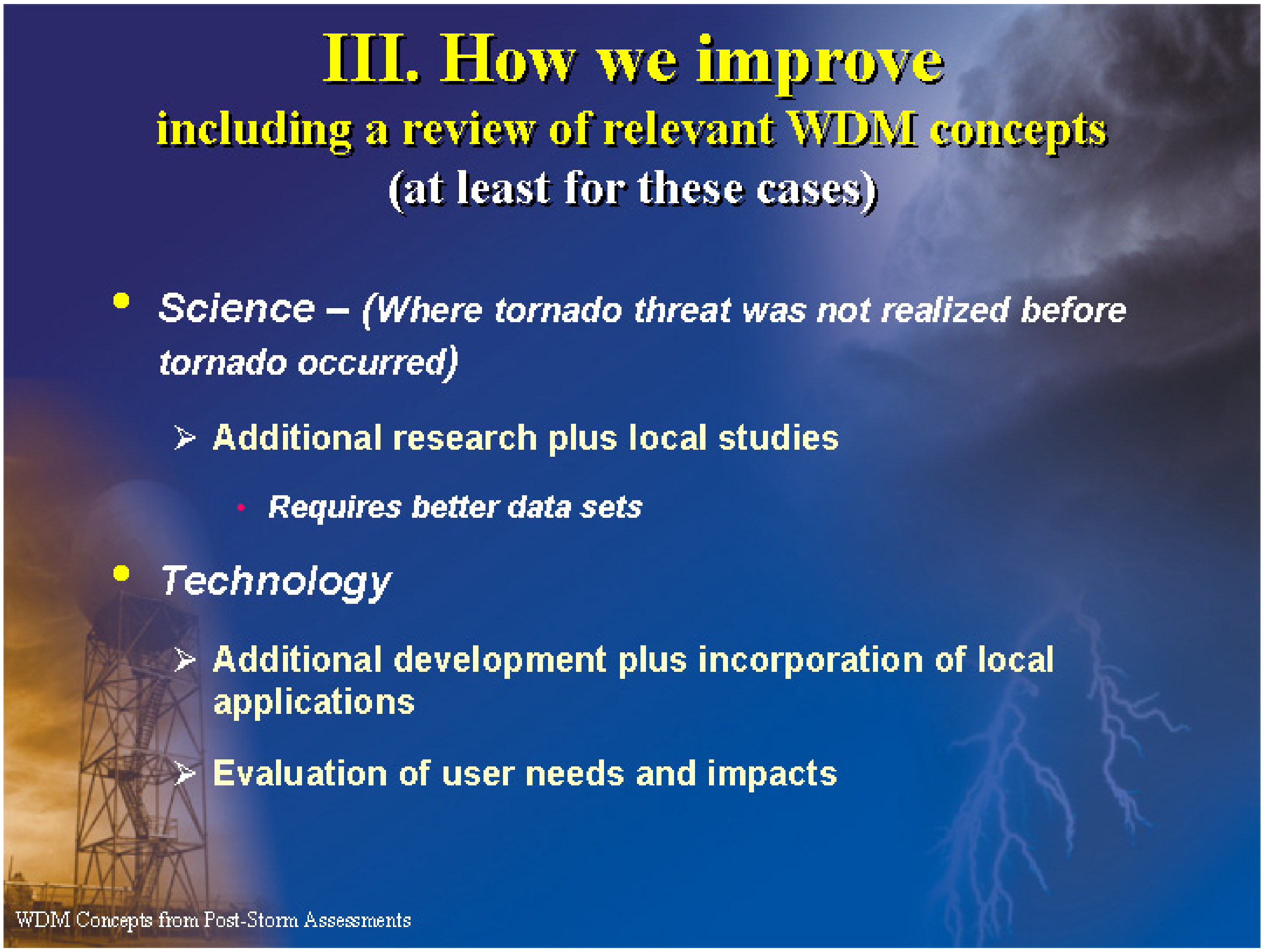
As I said the way we are kind of looking at the science right now is rather simplistic but looking whether or not there was a watch in place and what type of watch perhaps. Having a good idea of the science in our mind, in our background helps shape our expectations. And having that expectation allows us to react in some cases more quickly then we would had not had that expectation. In the five of twelve cases we had a severe thunderstorm watch in place, and one of them we had no watch in place. As I said, it is fairly simplistic but it does give you an indication that at least five of the twelve significant tornadic events had we been waiting for the science to be revealed by, for instance, the criteria for a watch either, in our heads or by SPC then we've totally missed an opportunity to see other things developing outside that expectation. So we look at these cases at if we want to go further, what was there that we missed in the science, if there was anything or is it just one of those things we just don't understand yet.



So let's look at the technology contribution in the seven of the twelve cases where it was indicated to be a challenge. In two of the cases, range folding was an issue, and sometimes we can do something about range folding by changing the PRF. Sometimes that still won't have an effect. Radar sampling is another problems. We can't control how the earth curves, and how small storms are sampled at long ranges, pretty much all we can do is change VCPs. The other thing we can do for both of these perhaps, would have been look at another radar view. It may not always give you the answer but it could give you more information. But it was an issue in three cases. In one case, algorithm guidance was mentioned and this begs the question, that if you are waiting on algorithm guidance, then perhaps, that is not the best course of action and there will be times where you will not have mesocyclones or TVS's detected and if you are waiting for the information, then perhaps you will be caught off guard if you are not looking at base data, for instance as your primary source of input. Equipment malfunction was highlighted in one case and the warning process of dissemination was also an issue. So these are areas that played a role in the technological contribution to not so great outcomes in these twelve events.

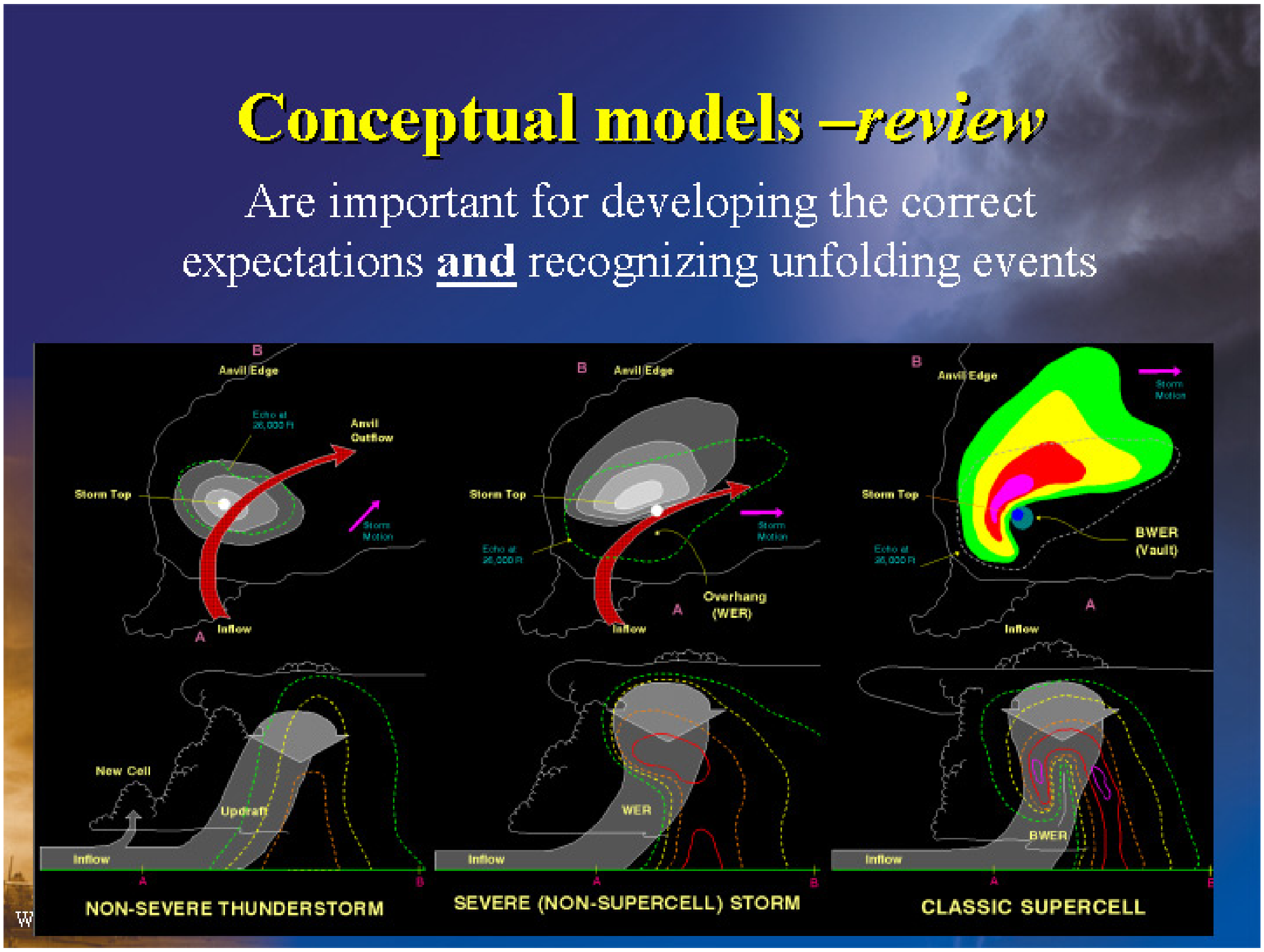


As I said before, there were human factor contributions with all twelve events and that should be no surprise since we are all humans and we do what humans do. But what do I mean by that. In eight of the twelve cases, it was the problem with applying a conceptual model. That in these cases was a cyclic tornadic supercell and comma head tornado and this is one of the reason we have put a review of conceptual models in this presentation. But what do I mean when I say that – applying conceptual models is a problem. In looking at these events after the fact, if most well trained folks would look at this and recognize this as a cyclic tornadic super cell that should be recognized in real time then I'd say there is a problem with applying the conceptual model if it wasn't recognized in real time. The question is why is that, why was that the problem. Is it that is wasn't recognized, or not understood, or never even saw the appropriate data. We talk about that a little bit more when we get into situation awareness part which was also an issue in twelve of the cases, in all twelve cases. Situation awareness is greatly impacted by the strategies you use, whether it is sectorizing, the procedures you choose to use on your AWIPS work station, the RPS list you choose, looking at other radars, changing RPS lists, you can also have a problem with your attention when you have lots of things going on that can cause you to miss something. Situation awareness is directly related to work load and that was an issue in four of the cases. Spotter reports, they certainly allow us to update our mental model, our conceptual model as well as our situation awareness and there are times that they are not being received or not available. Organizational issues such as the roles and responsibilities, partnerships, communication issues, face threat, meaning the ability for anyone on station to have a contribution without fear of retribution. The youngest intern saying something to the most seasoned warning forecaster in the office, as long as they can do that, then there isn't a face threat. But in some cases they may be a little too intimidated to speak up when they might have the most important information there. So these were some of the contributions made in the human factors each having a different solution.

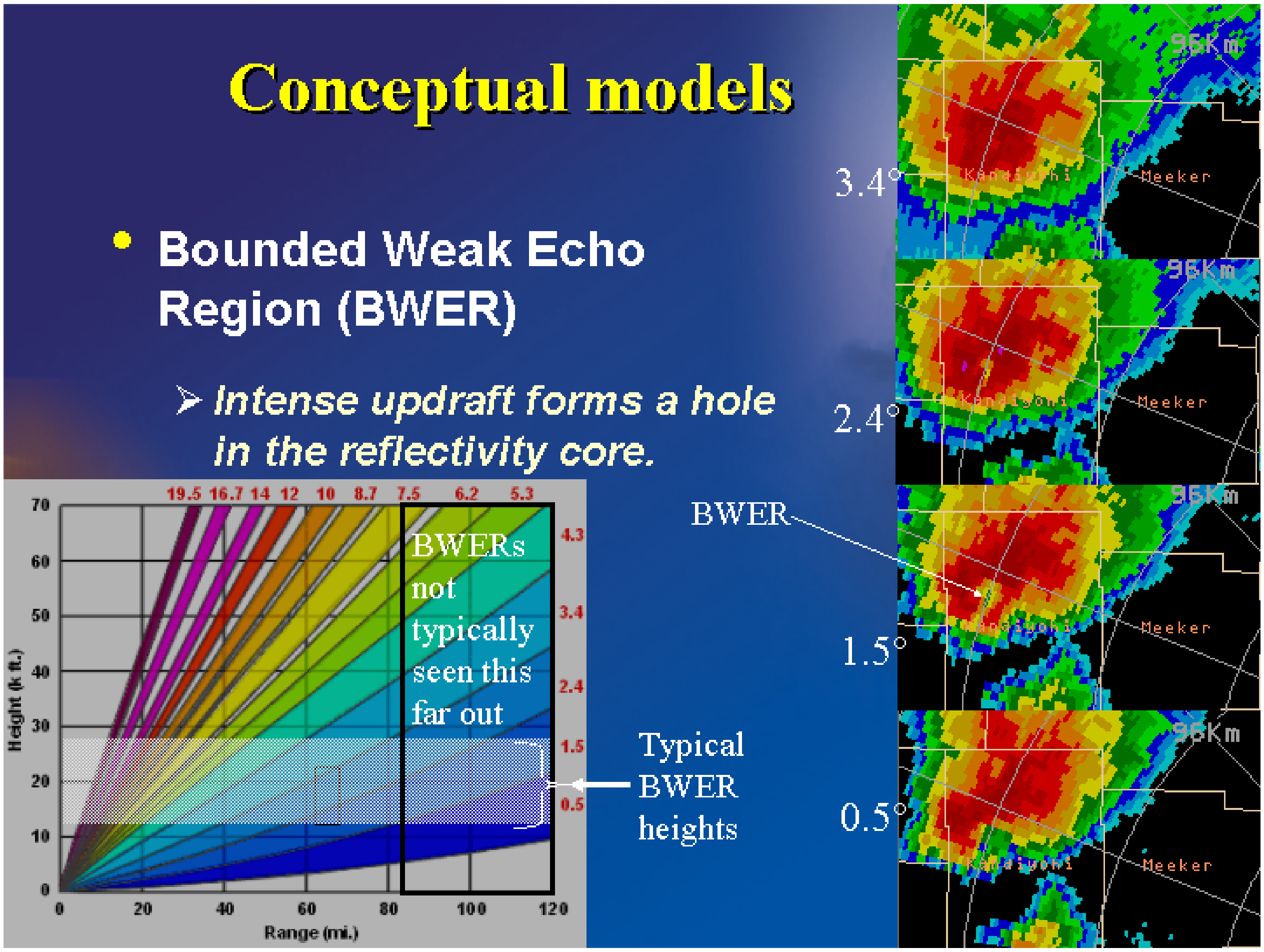


So what is going to make a difference? If we look at these twelve cases and we want to say, okay, what would have a made a difference in these cases, what do we need in the future, what can we do now, that would have had an impact for these twelve cases. For the science, well, if there is truly a void in our science, what is going to fix that is additional research and local studies, and better maybe data sets. If it is a failure for us to understand the science, then that is a human factors issue. But the fact that perhaps we don't yet know all there is to know about tornadic environments or they way tornadoes develop and how they are sampled indicates much more research needs to be done and that is not going to be a short term fix. What do we need for improvement in technology, well certainly, new and improved technology that incorporates what we have learned locally, what we have learned to apply locally is important, technology that evaluates the user needs and that we can access the impact on the user's methodology and strategies. We need those things to mesh, because it is a partnership between the human and technology that makes things work best.

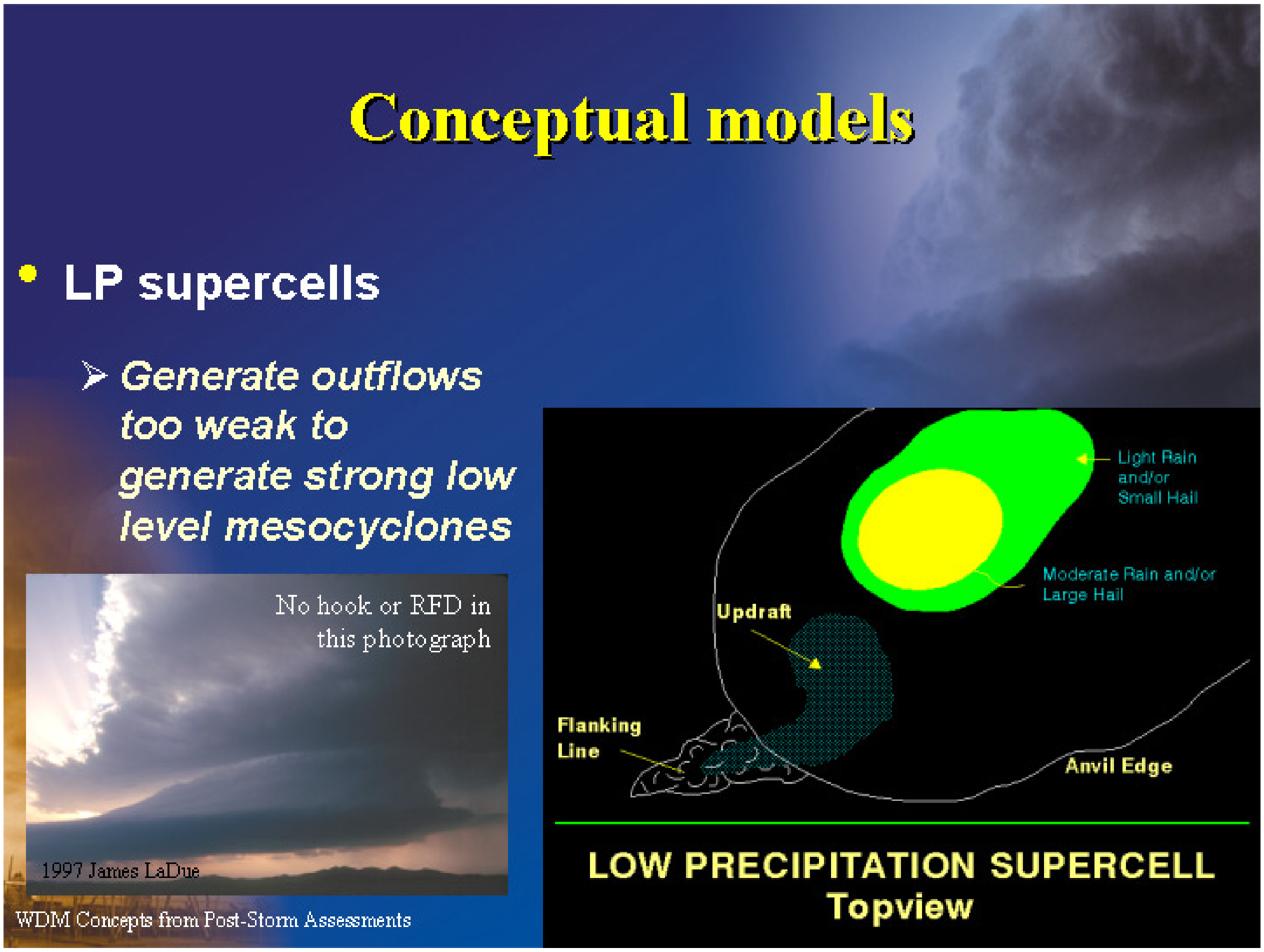
So what do we need as improvement in the human factors area. Well, if we look at these twelve events, one of the things we definitely need is to be able to understand and apply conceptual models and to that end, the next section will talk about a review of conceptual models that are most widely recognized and accepted. We also need an environment which supports good situation awareness and if you don't know what that is, we have provided a review of that as well, which you will see in just a few minutes. And we need effective office strategies that allows us to take the science, technology and make is accessible by whatever workstations we have, by whatever coordination and teamwork we have and we will give a review of some of the strategies that have seemed to work well over the past several years. And ultimately we need a warning environment in which we can communicate with each other, with our other partners and that coordination is made easy, in order for us to be most effective.



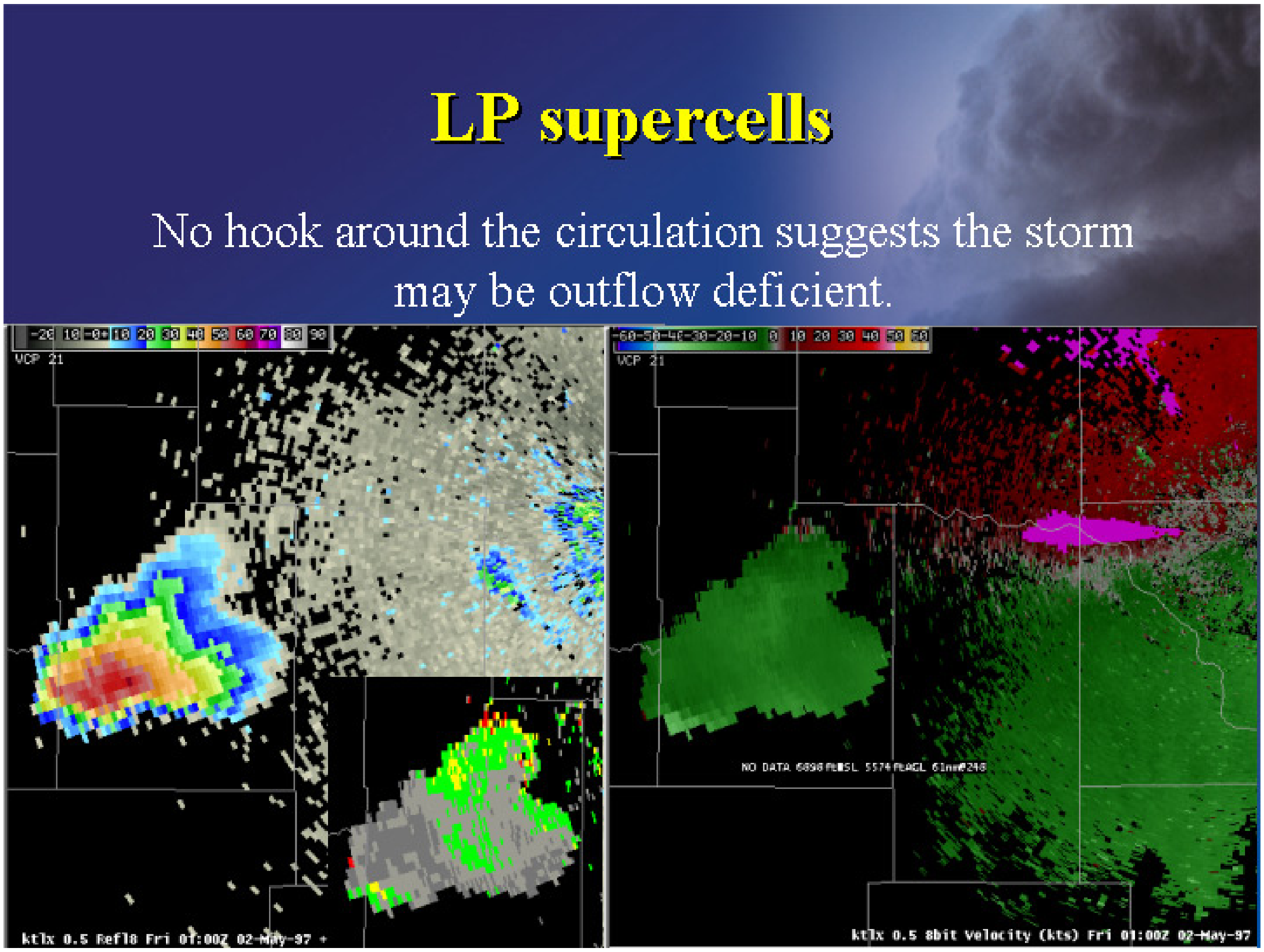
Okay, let's go ahead and take a look at some conceptual models. First, I would like to describe some of the reflectivity structure differences between storms that have severe updrafts and those that don't. Tornadogenesis often needs a strong updraft in order to enhance vortex stretching in the low levels. Les Lemon back in the late 70s and early 80s showed that thunderstorms that begin to develop updrafts tend to acquire different reflectivity structures then ordinary thunderstorms. Most thunderstorms will at first generate an elevated core with low reflectivities down below. However, that core cannot remain elevated for very long in a weak thunderstorm and you often wind up with a reflectivity structure in a cross section that looks like something like this. There is no weak echo region, there is no suspended persistent elevated core. When the updraft gets strong, this is what happens, the updraft again, is now able to suspend and keep elevated intense reflectivity core that typically begins around the mid levels, 5-6 kilometers and higher. This is called a weak echo region or echo overhang, low reflectivity down below and intense reflectivity aloft. This will often overlie and be adjacent to the inflow side at the thunderstorm at low levels and that side is where you have intense reflectivity gradience as you see here. When the thunderstorm begins to rotate, the weak echo region can actually acquire a characteristic where you have a weak echo hole that is connected to low level weak echo region down here and we call that the BWER. More on that in the next slide.



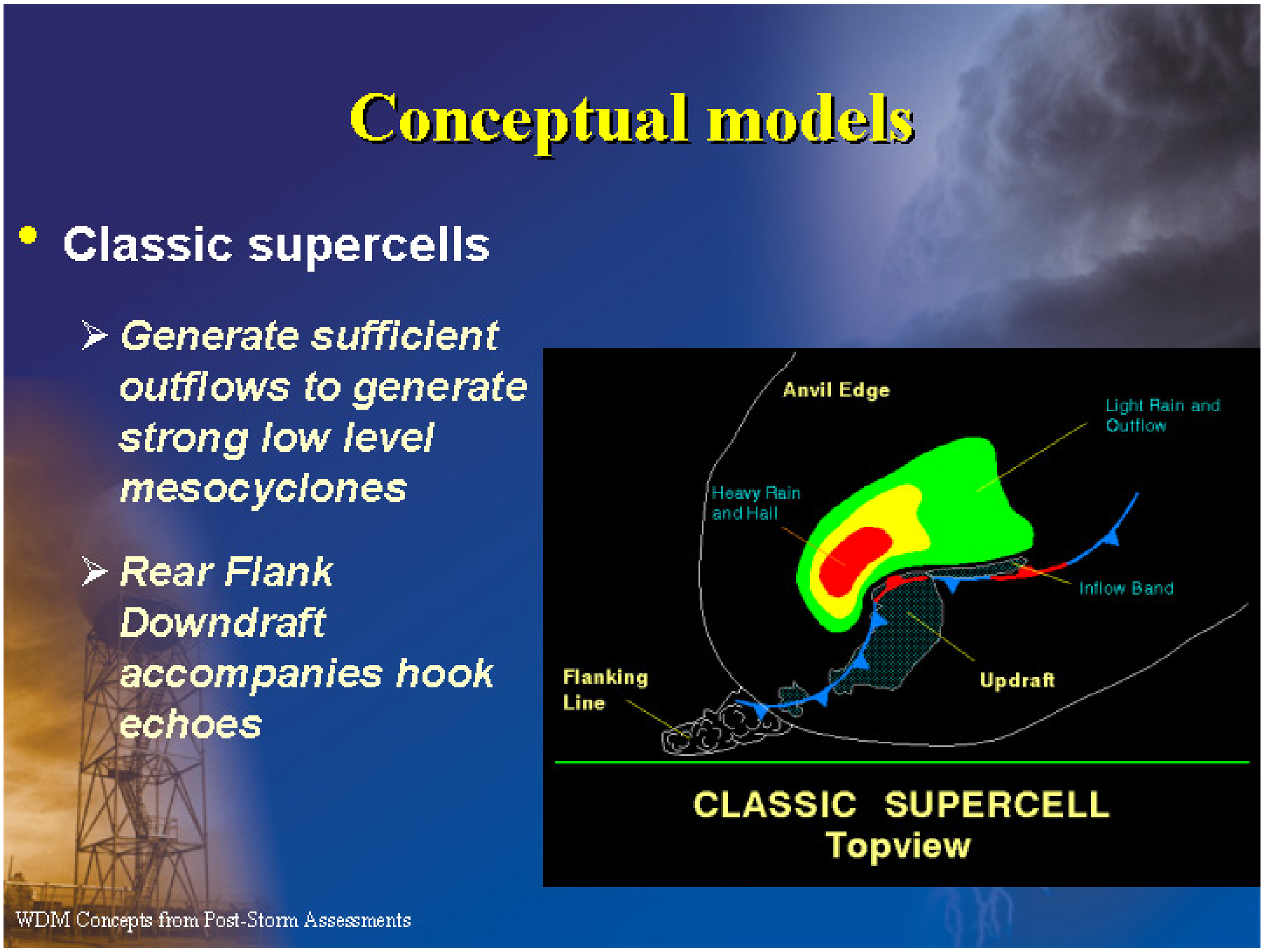
Lets talk a little bit more about bounded weak echo region or BWERs. Over here I have an example of a four panel stacked on top of each of a severe thunderstorm in northwest Minnesota. You can see the classic features of a BWER. At low altitudes it is basically weak echo region with the typical concave shape strong reflectivity gradient adjacent to it, that indicates a very strong low level updraft there, a large hook on the left, it doesn't have to be large, it could be small, maybe not even one at all. At higher altitudes, the precipitation starts enveloping a central core of weak echo until at high altitudes or mid altitudes you get a doughnut hole appearance in this BWER surrounded by intense reflectivity. A BWER forms either one of two mechanism, one is that you have a very intense updraft that is unable to form large hydrometers until high altitudes, or two, it is strong mesocyclone that is able to wrap precipitation around a central core effectively closing off a doughnut hole, in either case, you have a very intense storm. BWERs will typically last more than one volume scan, some pulse storms generate one for maybe one volume scan but it is not a persistent feature associated with a supercell. Also you have a connection between the inflow side that is notched, the weak echo region and then aloft, so that sometimes you might see things that look like doughnut holes but they have no connection with a low level weak echo region and inflow side, then it is not a true BWER. Over here on the VCP, you can see typical regions where you expect BWERs. Typically they are greater than 12000 feet to 28000 or so and since they are small you won't see them out very far from the radar.



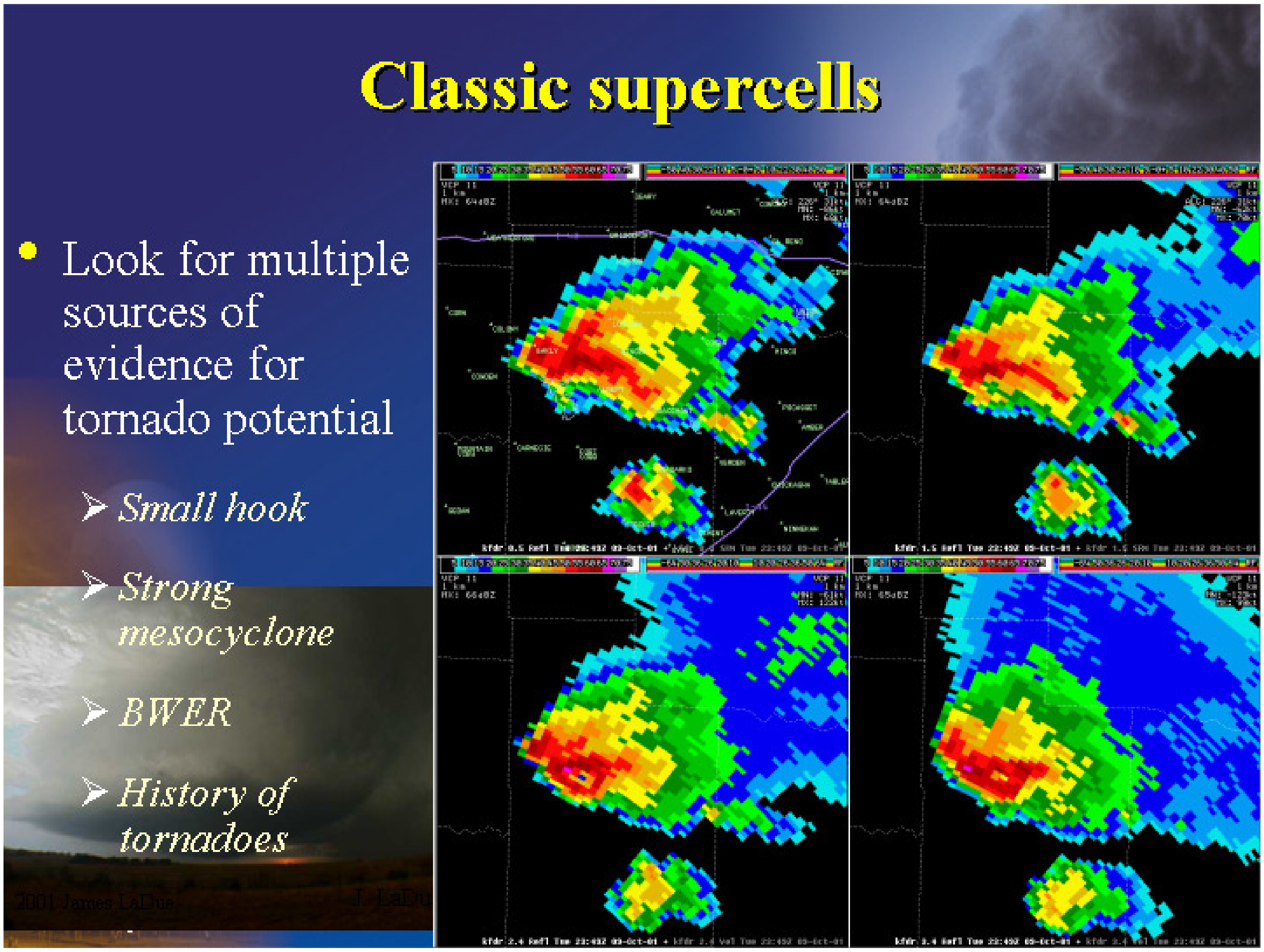
Trying to figure out what kind of supercell you have is fairly important because the kind of supercell that you have also kind of helps you decide what kind of severe weather is expected out of it. There are three types that we will talk about. The first type if the low precipitation super cell, we will call it LP storm for short. LP storms are very inefficient precipitation producers. They often produce reflectivity cores that don't seem to have any hook echo, the maximum values of the reflectivity core may or may not be large, they often contain large hail but often the outflows generated by the precipitation are too weak to generate strong low-level mesocyclones. So from a spotter point of view as in this picture here, you may see a flat cloud base, not very much precipitation off on the side of the core and no real strong indications of strong low level rotation in the cloud base or let's say any kind of rear flank notch, you won't see anything like that. These storms are generally hail producers but they have very low chances of producing significant tornadoes.



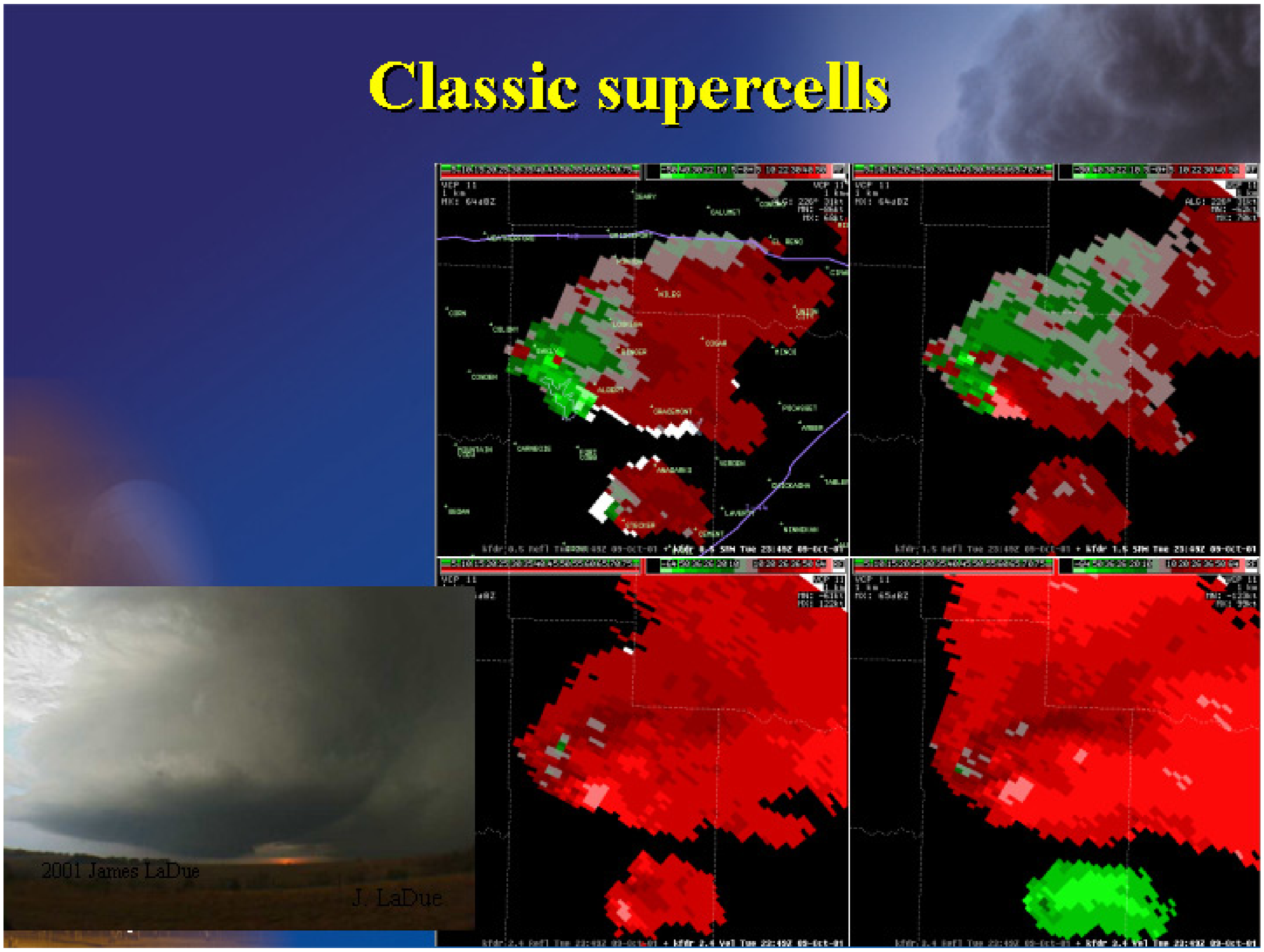
Here is an example of the LP super cell on the radar from which the picture was taken in the last slide. Take a look of this here, the radar is off to the east, up in this way, the beam elevation at the storm is roughly about 6000 feet above ground level. The photographer was off to the east southeast of the storm looking west, northwest and the actual updraft is sitting right here, kind of a rough circle, just south and southwest of the reflectivity core. The actual values of the reflectivity are pretty high, they are about 60 DBZs, there is likely some pretty good size hail in here. There is no hook echo observable from the radar, at this point here. The velocity, it is 8 bit velocity, and it shows that there is some shirr, we have enhanced inbounds on one side, roughly about 30 knots or so and on the other side, we see weaker inbounds, maybe 5 to 10 knots, so it is a very weak mesocyclone although there is some rotation, but this storm does not have enough rotation at this point here, to be a significant mesocyclone. Certainly, the one thing is that there could be a hook echo below the radar beam, in this case, but from the spotter point of view, the spotter didn't see anything and from this radar, it doesn't show a very intense mesocyclone, so, likely this is really an outflow deficient super cell or what we call an LP super cell.



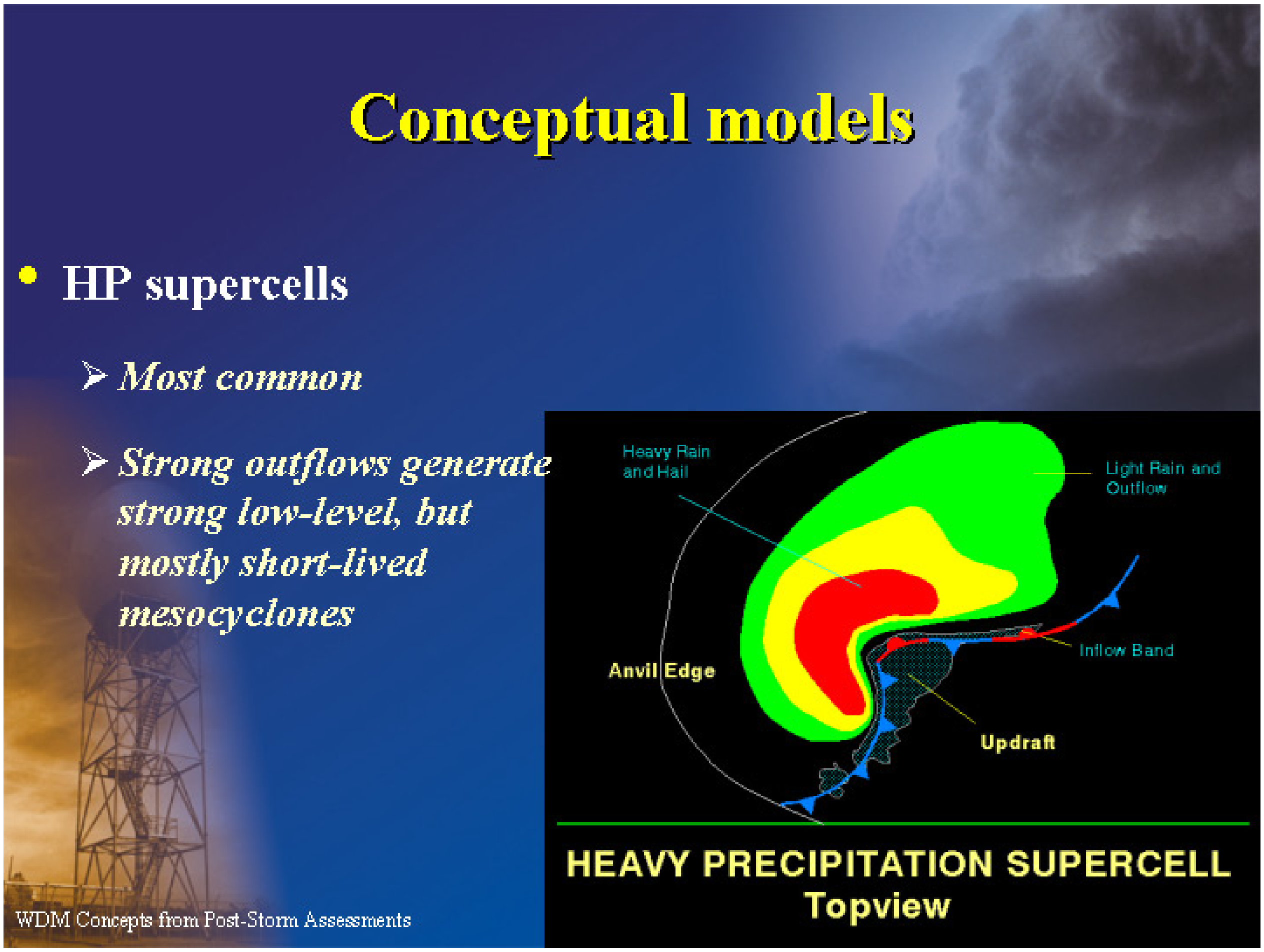
Let's so ahead and go from LP super cells up to Classic super cells. The only real difference between the two, is how efficiently the super cell can generate precipitation and classic super cells are typically more efficient than LP super cells. A lot of times we will define a Classic super cells, as that kind which has sufficient outflow to generate a significant low-level mesocyclone. If you looking on your radar image or from above, you would see a core that showed more of an inflow notch and more of a hook echo on one side of the storm. The reflectivity values can be as large or even larger than even LP storms just because there will be a lot more precipitation and large hail within the core itself. The distinguishing characteristic of classic super cells is going to be a significant rear flank down draft, one that accompany a significant hook echo but something that not be too large. These kind of storms are the ones that often produce the longest lasting and most damaging tornadoes.



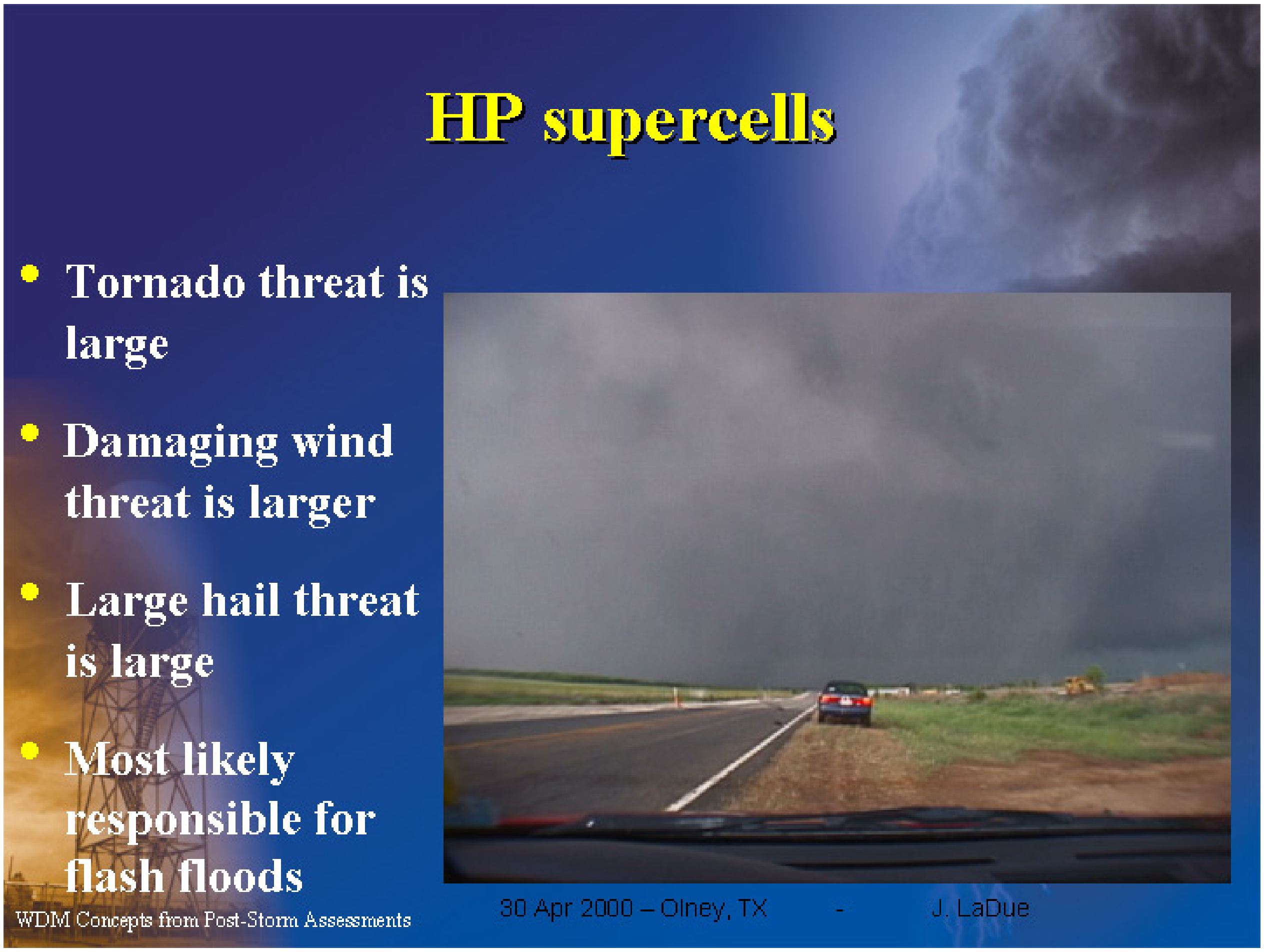
In this example of a classic supercell, we can see that there are actually several signatures that indicate the ingredients for tornadogenesis are here. For example, small hook echo, you can see the hook echo right here, looking over in the velocity, you can see the hook echo represents strong inbounds as viewed by a radar from the southwest. This indicates that there is probably a rear flank down draft that is creating outflow at the surface. In addition, evidence for a strong mesocyclone are certainly there.



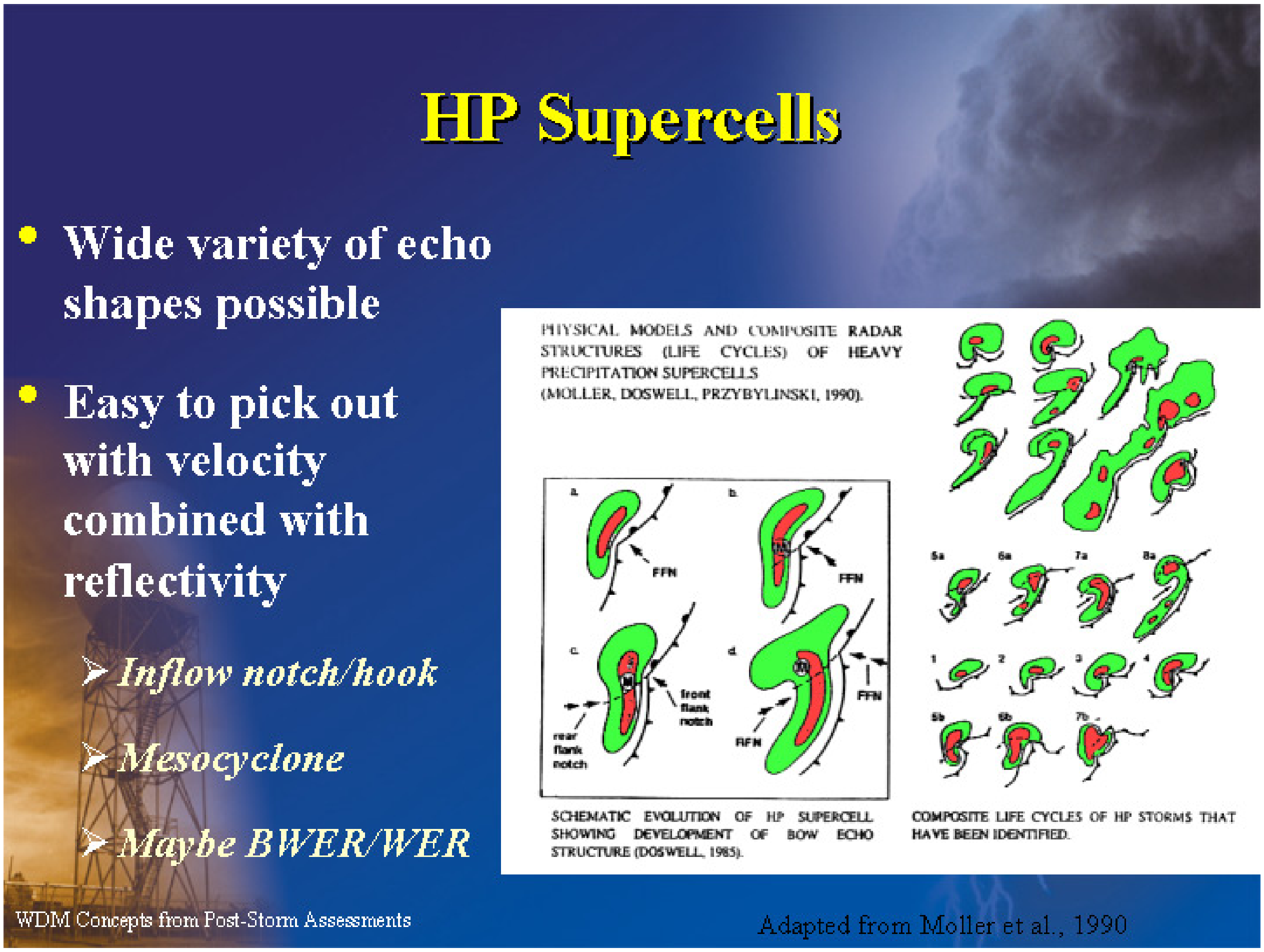
As you can see here, all four panels show a strong velocity couplet. Notice that the lowest panel has somewhat weaker, kind of a strange velocity signature here, we believe this is because there is some dealiasing occurring on the inbounds and this often occurs with very strong mesocyclones. So that is a good sign too, and you can see that the mesocyclone extends to high altitudes. So we have a strong mesocyclone. We found a weak echo region, now we are looking for indications of a strong updraft, and you can see that we have, down at low levels, very strong inflow notch here with a sharp reflectivity gradient with kind of a concave structure to that gradient right there. That is a good indication that there is strong updraft going on at low levels and that persists as a closed off bounded weak echo region aloft. That is a indication that we have a very strong updraft in addition to strong rotation. So we have three perameters here that we are looking for. Finally, down here, history of tornadoes, it so happens that this storm has a history of tornadoes, although they were small. And, so the history of tornadoes, tell us something about this storm in which we can't get from conventional radar data. It is all the parts of the storm that we don't understand about tornadogenesis, that seems to be working with the storm and so that is why history is so important. And as you can see from the image here in the spotter, we have a classic supercell appearance, very large circular updraft with a lowering down here, general cloud bases are low, and no signs of strong or over abundance of outflow here. This storm should have a tornado warning.



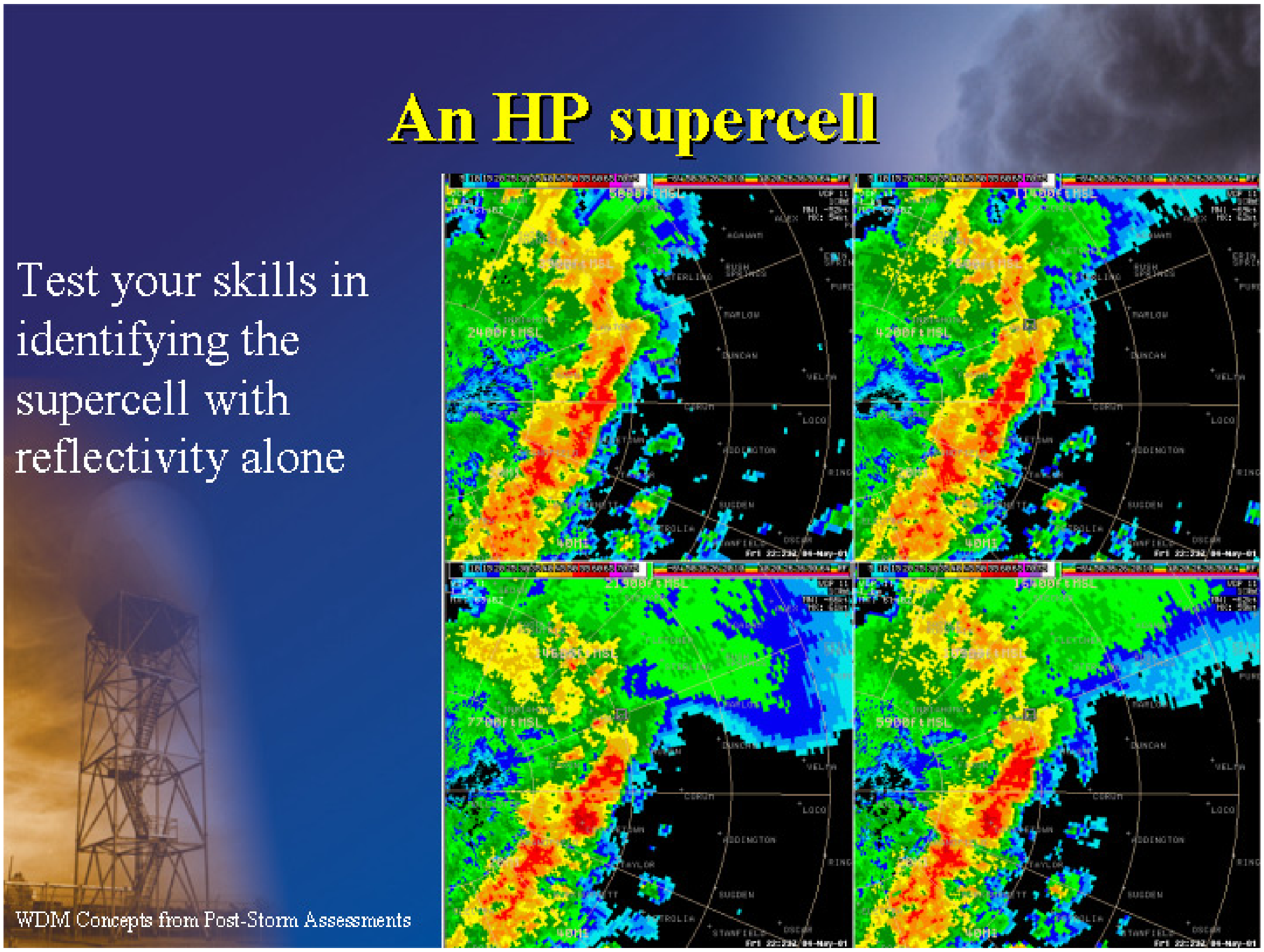
As we start generating more and more precipitation out of a supercell, we start getting to a point where the supercell takes on high precipitation characteristics. So we call these types HP supercells. These are the most common types of supercells, especially in the more moist climates east of the, well east of the Rockies, especially east of the Mississippi. These kinds of storms generate very strong outflows. They can generate very strong, but mostly short-lived, mesocyclones. Certainly though all the threats are there for these kinds of storms because they can generate low-level mesocyclones so quickly. You often see in a reflectivity diagram, like in this conceptual model, that the hook echo becomes extremely large relative to the forward flank portion of the core. In some cases as we'll see next, the hook echo can be the dominate reflectivity structure in the storm. But you can see that there are some characteristics that are very similar including somewhat of a concave structure with a sharp reflectivity gradient on the side of the inflow. And you'll see a very strong mesocyclone and other things like that. So all the characteristics of supercells are there, these just happen to generate more precipitation.



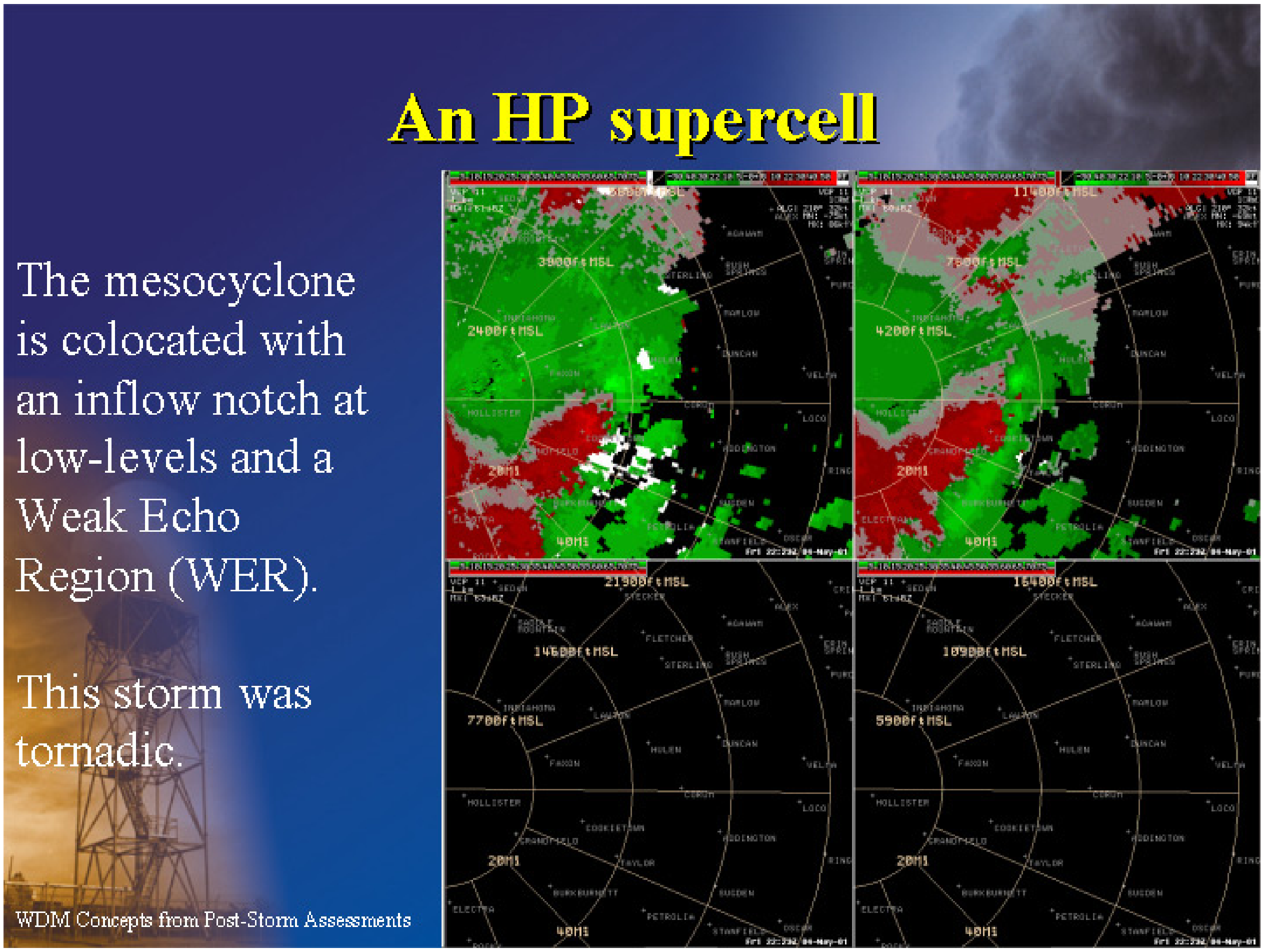
HP Supercells represent a significant problem for getting ground truth reports. A lot of times ground truth is impossible because the hook echo becomes so large it completely envelopes the point of low-level rotation. Here you can see the rain fall falling out of the hook echo all the way off to the right of the road here, however, the point of rotation is sitting just to the left of the road. In fact you can barely see there is a significant tornado there residing left of the road, coming towards the spotters point of view. However, a lot of times you wouldn't even be able to see that. So this does represent a problem for a warning forecaster because the warning forecaster ometimes can not rely on getting that ground truth before pulling the trigger on the tornado warning. So you may have to rely on radar data a little bit more than ground truth. Even in places where you expect a lot of ground truth reports you might not get them. Tornado threat is large for HP supercells, just like classic supercells. Damaging wind threat is even larger than for classic supercells because of the intense precipitation. Large hail threat is very large. In fact, some of the worst "hurricane hailers" we like to call them, come out of these kinds of storms. Those are the kinds of storms with extremely large hail accompanied also by very strong winds at the same time. And these storms can represent a significant flash flood threat because the precipitation rates are going to be so high.



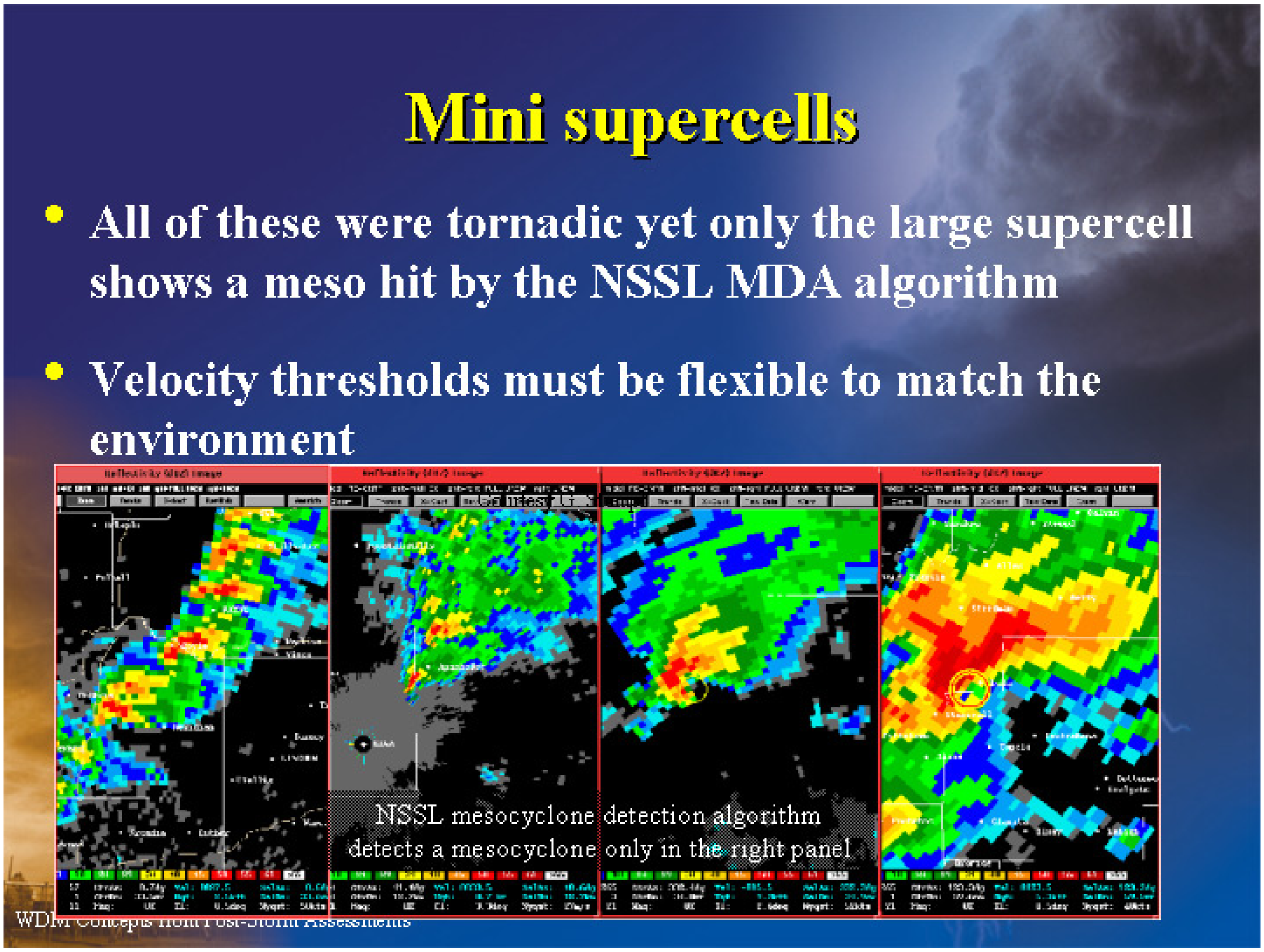
HP supercells come in a wide variety of echo shapes and that is because the hook echo sometimes becomes the predominant reflectivity structure in the entire storm. And other times it's the forward flank core that's really large but there also happens to be a large hook echo coming around the center of the low-level mesocyclone. Here's an example, this is from Mollar, et al 1990, where they looked at several different types of reflectivity structures that you can see with supercells. There are similarities though. One of them is that mostly in the low levels you'll see some kind of concave reflectivity notch with a sharp reflectivity gradient and that represents the point of the low-level updraft. And it also gives a clue that there is some kind of rotation going on at low levels there. In some cases you may see a comma head structure like this down here and also in some other cases you may see multiple points where there is inflow notches coming into this reflectivity core and the HP supercell might be accompanied by more than one mesocyclone. Other reflectivity structures that you'll see, maybe you'll see a weak echo region and a bounded weak echo region. Any significant HP supercell with have a mesocyclone too.



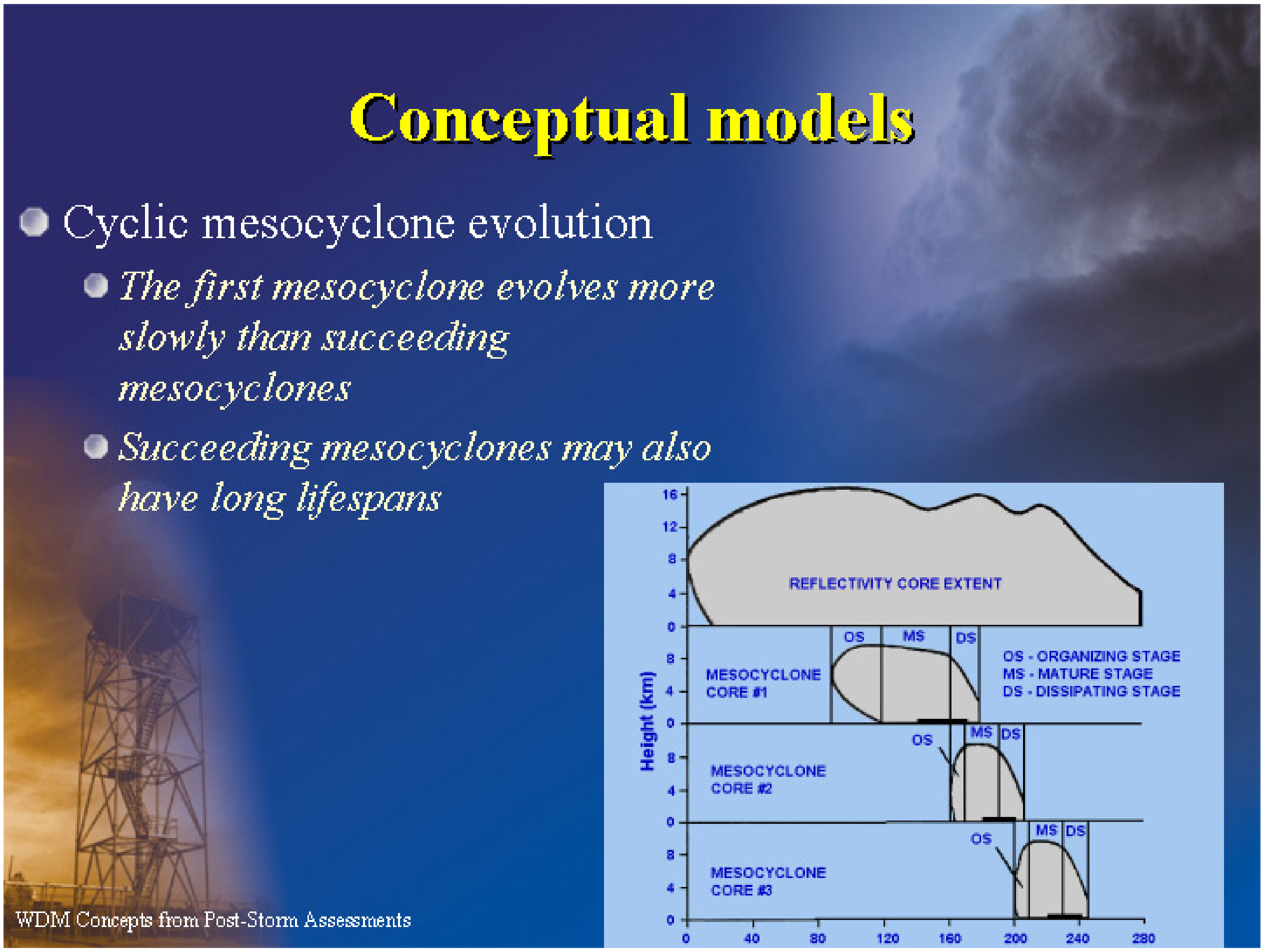
An HP supercell environment might contain complex reflectivity structures, but within there you should be able to pick out where the HP supercell is likely to be just looking at the reflectivity here alone. Any kind of HP supercell should have a good reflectivity notch or an inflow notch down at low levels, and that notch should be surrounded by a high reflectivity gradient in a concave shape. At higher elevation angles, here and here, you should see some kind of weak echo region or an area of suspended reflectivity core that will be overlying that reflectivity notch. The good thing about HP supercell environments though is that there is an awful lot of precipitation which provides a good sampling environment for detecting a mesocyclone. This is in contrast to LP storm environments where often the mesocyclone has no precipitation around it and is nearly impossible to pick out by radar.



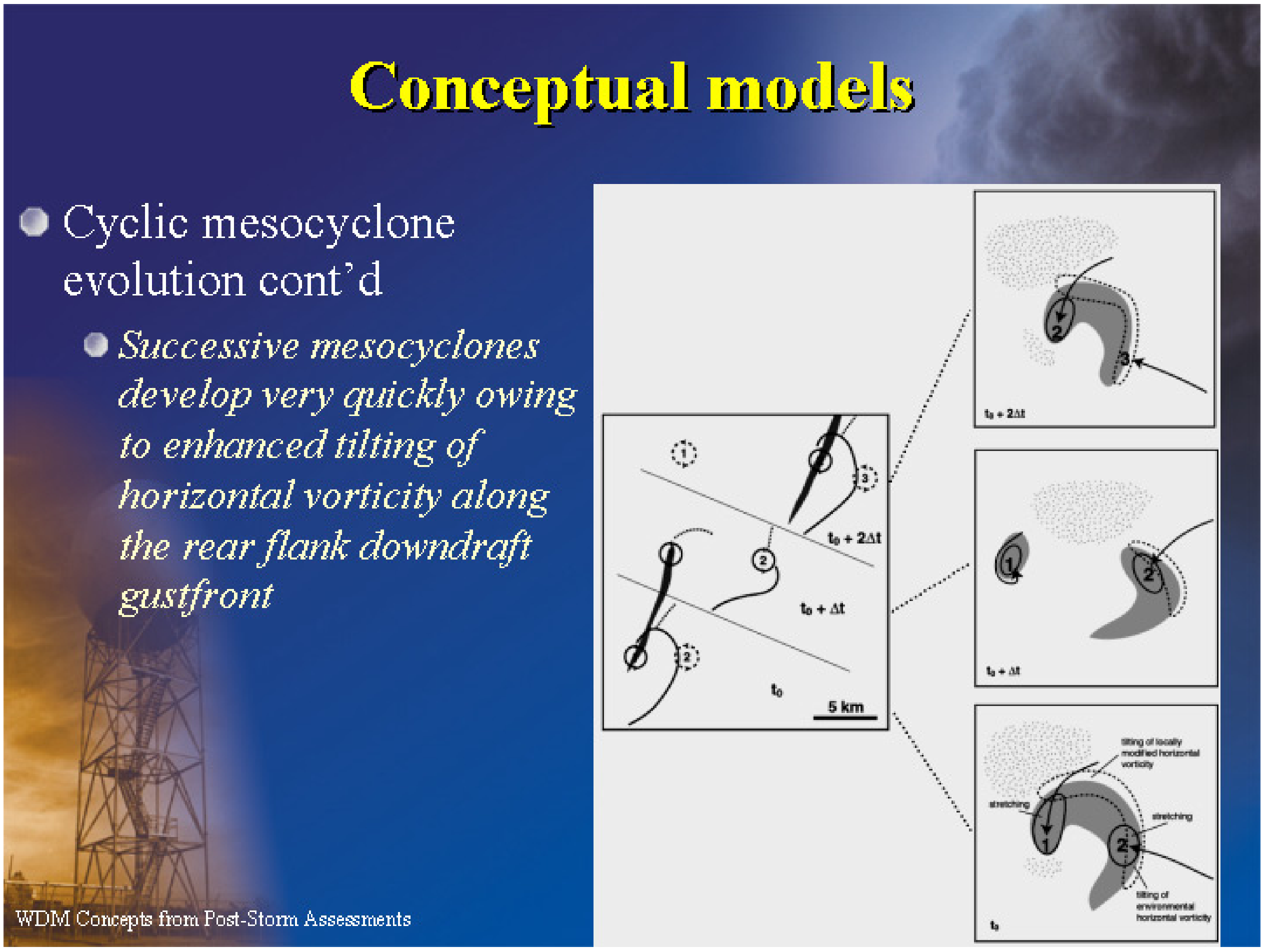
So here it is. There's the mesocyclone. We can see in these two slices there's vertical continuity. So let's take a look back at reflectivity and see if that mesocyclone is coinciding roughly with the inflow notch at low levels and it sure is. There it is right there. So that's a good sign. We have evidence of strong updraft, evidence of rotation here as well. This storm here is something to watch out for, especially if the environment is good for tornadogenesis and this day it was. And in fact in a few minutes later, after this point, a large rain-wrapped tornado formed in this. The echo tops were only up to 30,000 feet, technically this is a mini HP supercell.



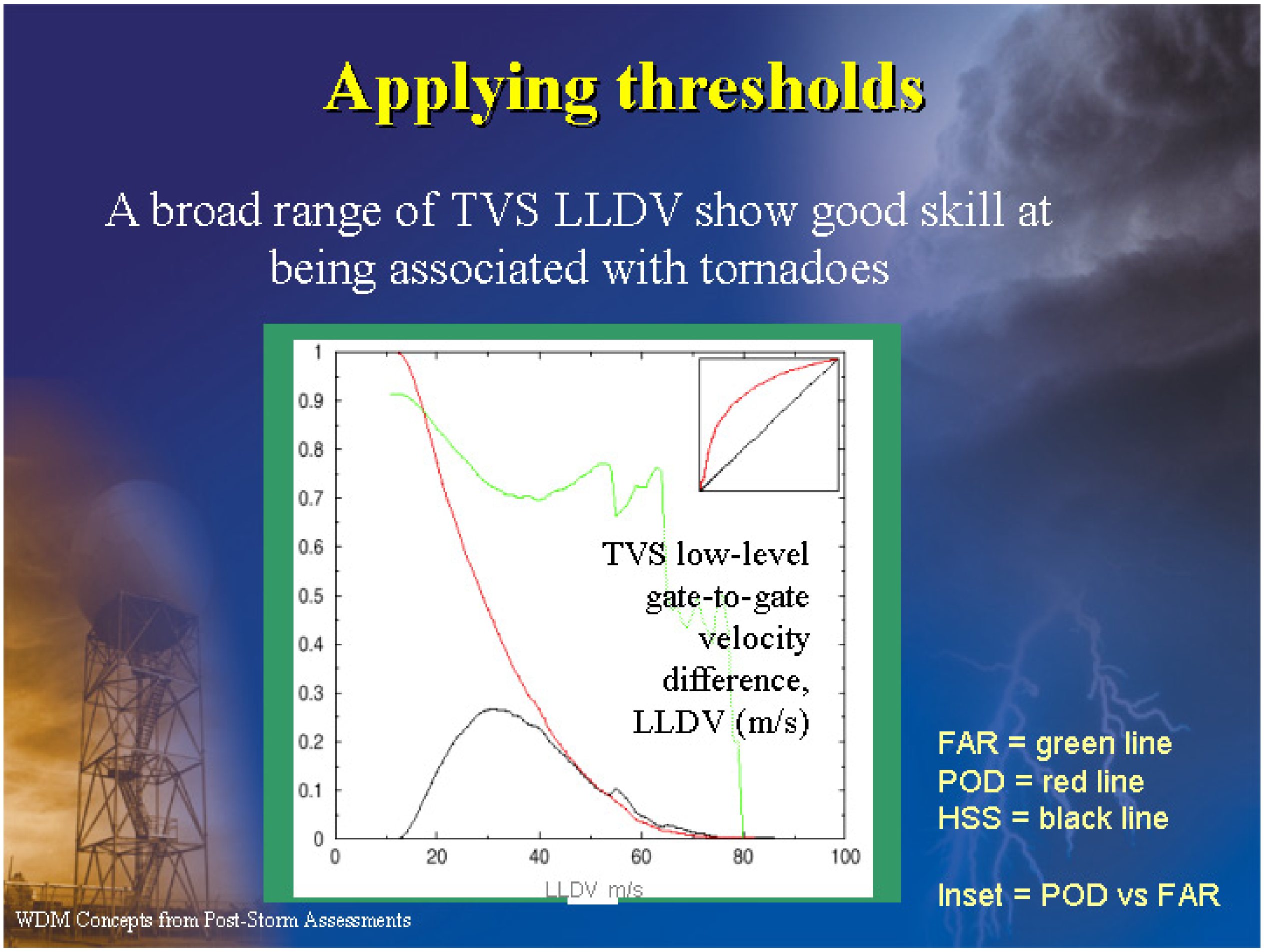
Speaking of mini-supercells, take a look at this 4-panel down below. This panels are all at the same map scale, but showing different storms of different sizes. Using the NSSL mesocyclone detection algorithm, only the mesocyclone in the right panel could be detected by this algorithm, and as you can see, the only one with a true meso. The one in the second to the right only has a weak shear signature and then one over here in the middle left, no signature whatsoever or with that to the far left here. All of these are producing tornadoes at this time of about the same intensity but you can see the one in Colorado is almost impossible to detect and certainly the one near Phoenix is. And the ones northeast of Oklahoma City are also. So be careful about mental velocity thresholds, make sure they do match the environment. And the other thing too is that different types of storms can occur in the same observable environment.



When you have environments where supercells generate tornadoes rather prolifically, you get a situation where a single supercell can produce more than one mesocyclone (cyclic mesocyclone producing supercells can occur even without environments supporting prolific tornado-producing supercells). This represents somewhat of a warning problem here that you might want to get yourself out of just in case you recognize the situation. Let's take a look at this time-height diagram down here. This is reflectivity core extent here, this is the extent of the reflectivity in a time-height sense of a supercell that starts as an ordinary cell here, and eventually evolves into a supercell in time. The first mesocyclone may form about 80 minutes after the first reflectivity core develops and it will start usually around 6KM or somewhere in the mid levels of the storm, but the surface representation, or at least the low-level representation of the mesocyclone, might take another 40 minutes or so to develop. The problem is that you might get use to sitting around waiting for the development of that low-level meso for the next mesocyclone, but there might not be any waiting period. It might take as little as 5 to10 minutes for the low level meso to form for the second mesocyclone, and it might not even take any time at all. It might be the first feature that shows up in the second and all subsequent mesocyclones. Subsequent mesocyclones also may last quite a long time and in fact many times, it's not the first meso that produces the most intense tornado but it might be mesocyclones 2 or mesocyclone 3.

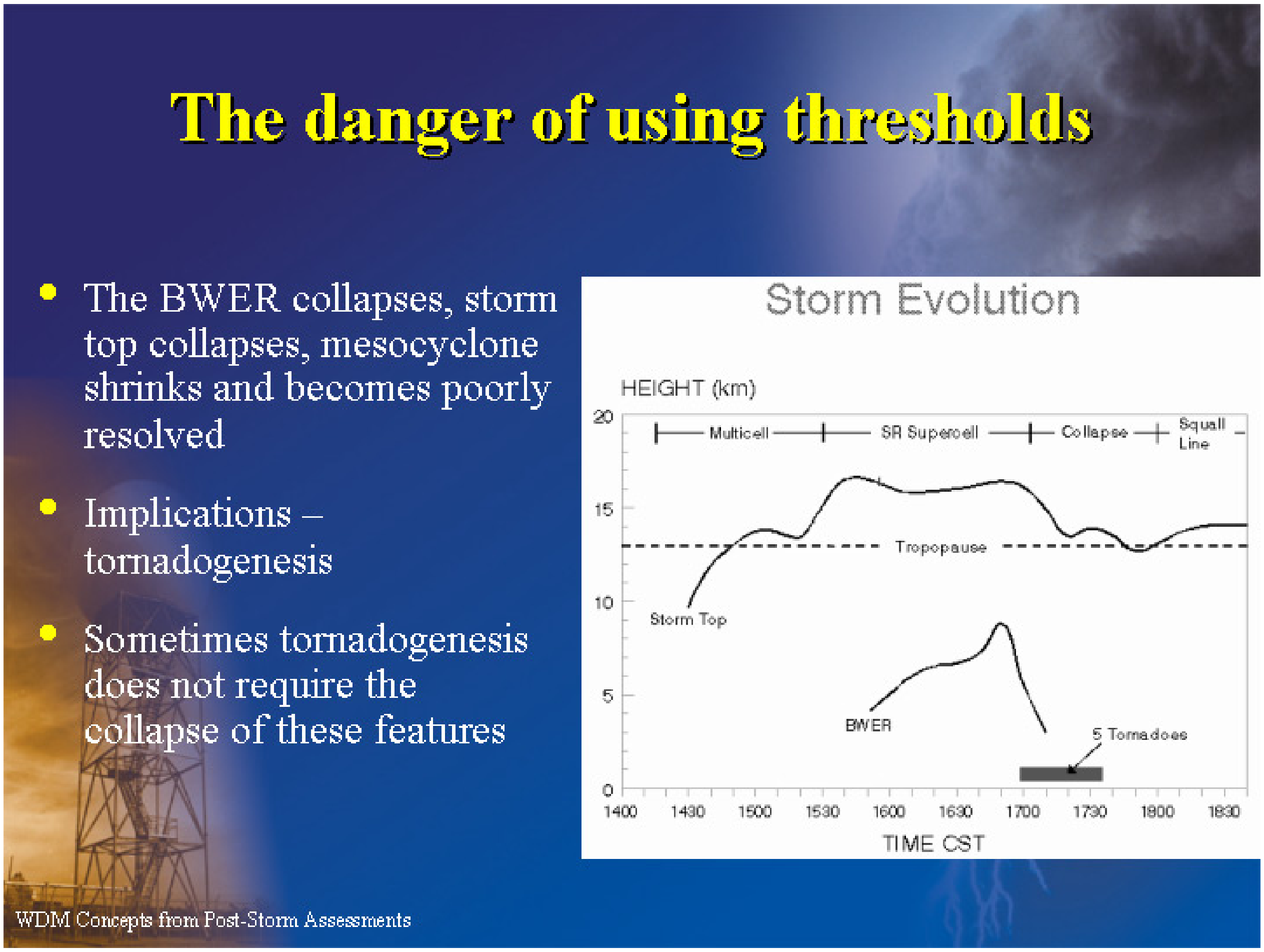


Okay, let's go ahead and take a look at why successive mesocyclones form so quickly. This is based on work that's hot off the press form Dave Dowell and Howie Bluestein looking at VORTEX data from aircraft radars and other data. Several supercells during that time have undergone similar situations like this one here. At first the first mesocyclone that forms is unable to develop at low levels. Usually it develops at midlevels and the low level mesocyclone has to wait until a rear-flank gust front is mature enough to stretch enough vorticity, so it does take a while for the whole process to develop into something where a tornado can form. But once it does happen of course you get the tornado and then it moves off to the left. But now you have a mature rear-flank gust front, strong convergence and lifting, producing an updraft (as seen here in the shaded regions). Along the leading edge of that, you have very strong intense stretching and tilting of the horizontal vorticity in the environment, and in some places you might have a locally intense convergence maxima that produces better stretching and tilting of vorticity and you wind up with the development of the new mesocylcone. That new mesocyclone has a jump start where the previous one didn't because it's already got a mature gust front to work on. And so it can develop low-level rotation quickly and subsequent tornadogenesis, which you can see over here. And successive mesocyclones can form in the same way producing tornadoes fairly quickly.

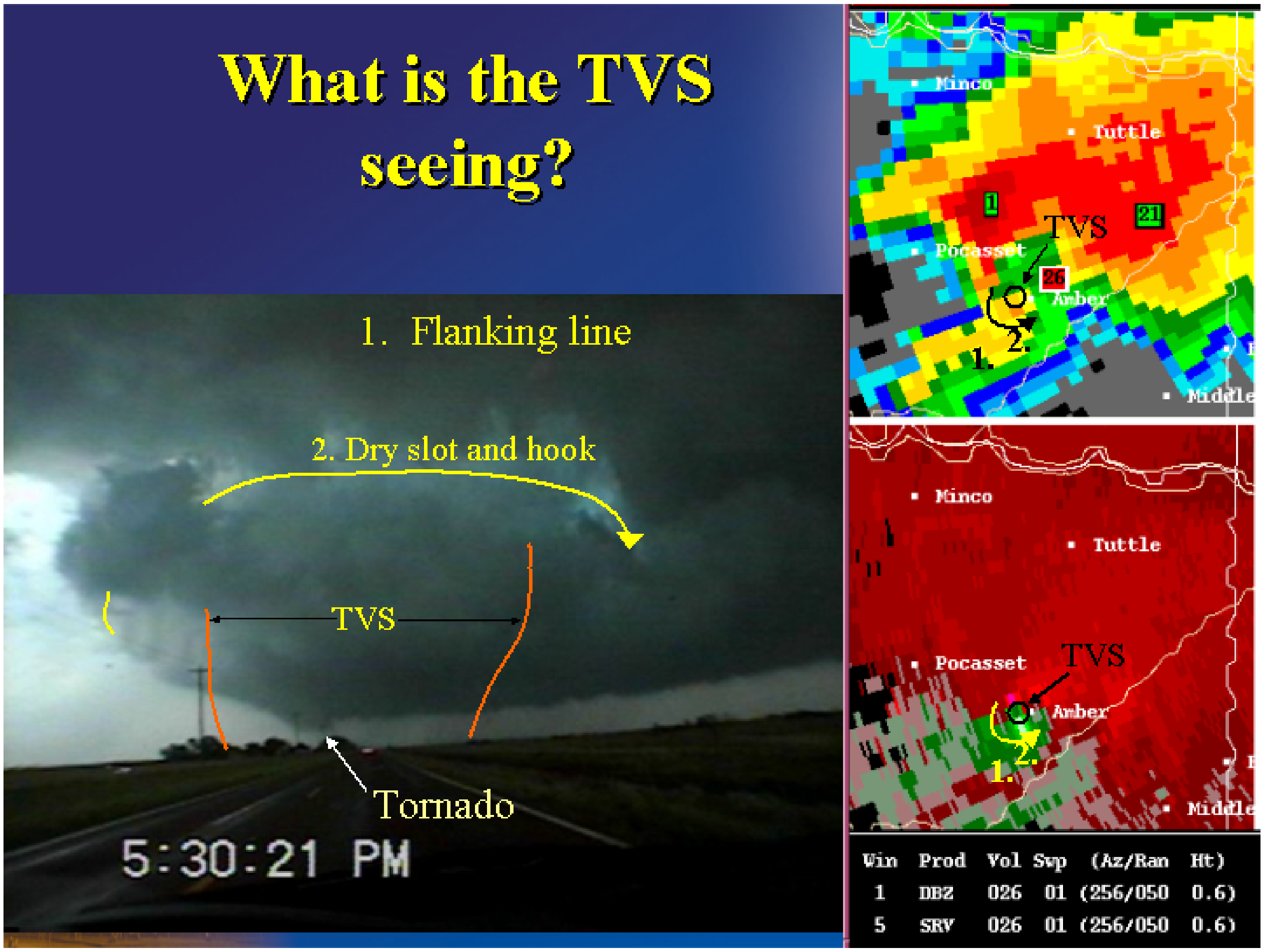


Okay, I'm going to go ahead and start talking about Tornadic Vortex Signatures and I'm going to talk about it here in context with applying thresholds and some comments about that. This is based on a project with the National Severe Storms Lab in which they looked at numerous Tornadic Vortex Signatures as identified by the TVS or TDA algorithm. They looked at thousands of signatures from across the country and came up with these statistics where they associated with the signatures the report of severe weather, and then looked at how well the signature performed given certain values of certain parameters associated with the Tornado Detection Algorithm. The one I'm showing here is the best parameter that you could use with TVS that we found out that had the best characteristics, best association with tornadoes. That's the low level gate-to-gate velocity difference or the LLDV. Notice the Heidke skill score, and that's the skill score that represents the best overall performance of this parameter, and you notice that it peaks out at about 35 ms-1 , but it's pretty high over a broad range and so there is no one specific threshold that yields a much greater skill score than any other threshold here. Of course after a while if you decrease it enough, your skill score goes down, but you have to be careful that there are some events out here in which a TVS with a very weak low-level delta V can still create, or be associated with tornadoes.

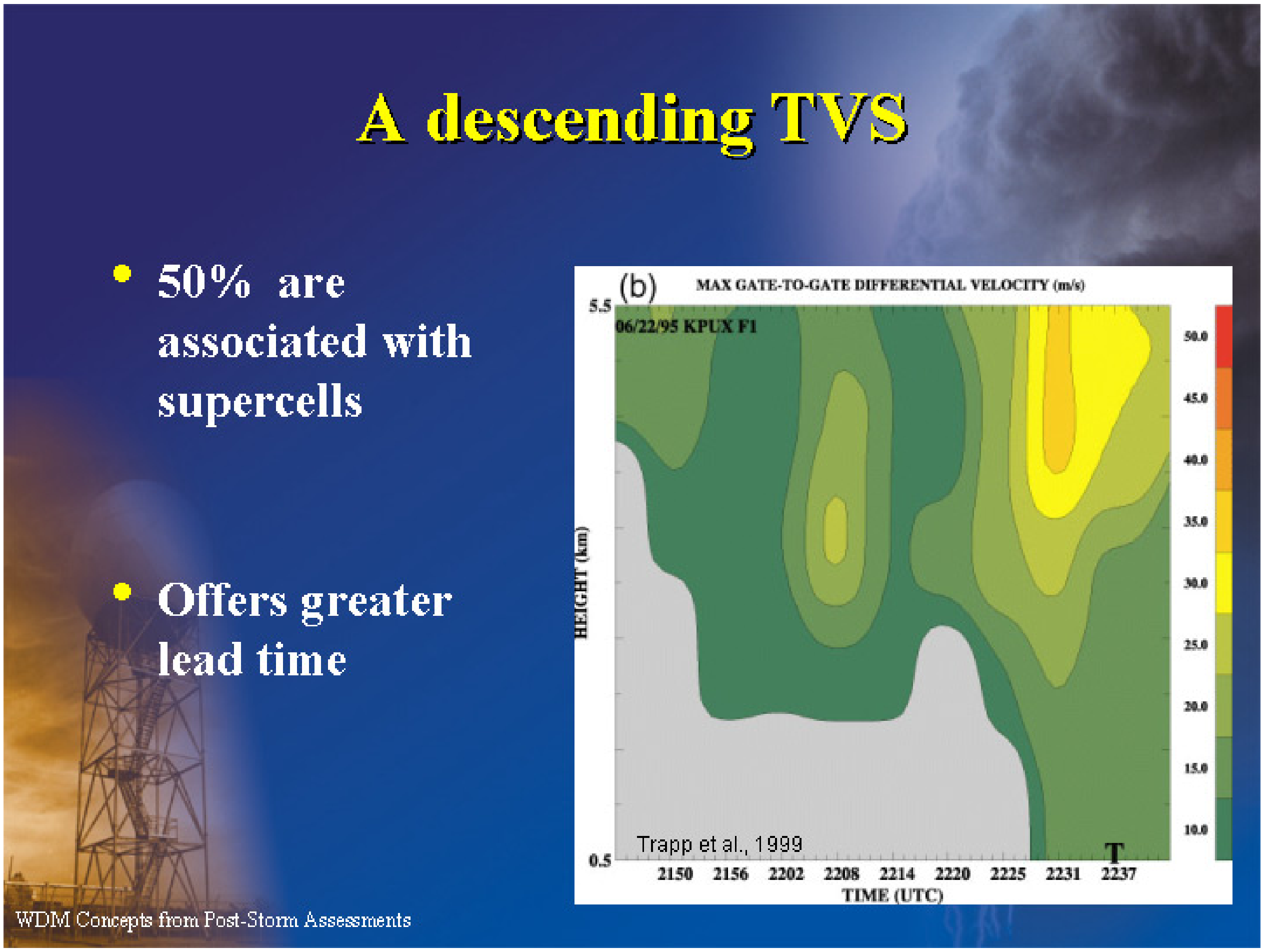
(Please see this tornado warning guidance web page at http://www.wdtb.noaa.gov/resources/PAPERS/twg02/index.html.)



Okay, we talked about the dangers of numerical thresholds, looking at a TVS example, but there's also a kind of a danger with a mental threshold, in other words, you require a certain number of pieces of evidence that a storm is tornadic before you issue a tornado warning. Sometimes some of those pieces of evidence may disappear immediately before a tornado and this is one example here. Back in the early 80s, Don Burgess looked at the time-height trends of bounded weak echo region height and storm top height just before several tornadoes formed and noticed that the BWER collapsed. In addition, just after that, the storm top dropped off a few kilometers, so it makes the appearance that the updraft has weakened. What really happened is that the upper level updraft weakened because a strong low-level mesocyclone formed just prior to tornadogenesis, and that reversed the non-hydrostatic dynamic pressure perturbation gradient. In other words, the forcing mechanisms suddenly reversed from enhancing the upper level updraft, to actually creating a weaker updraft and that's all because the most intense rotation started developing at low altitudes. So what often happens in many tornadic storms is that you'll see the collapse of the bounded weak echo region, the storm top might shrink a little bit, and the mesocyclone will contract. It actually becomes more intense but the problem is, is that as it shrinks, you might start poorly resolving it with the radar and it may appear to weaken. So the implications may be, maybe not the storm that is weakening but a storm that is about to produce a tornado. Now, will you see this all the time before the onset of a major tornado? Not exactly. It all depends on the individual dynamics of the storm and also how the radar is sampling it - are you far away or nearby? But the idea is that you don't want to hang on any one piece of evidence without understanding what the implications might be if that piece of evidence disappears.

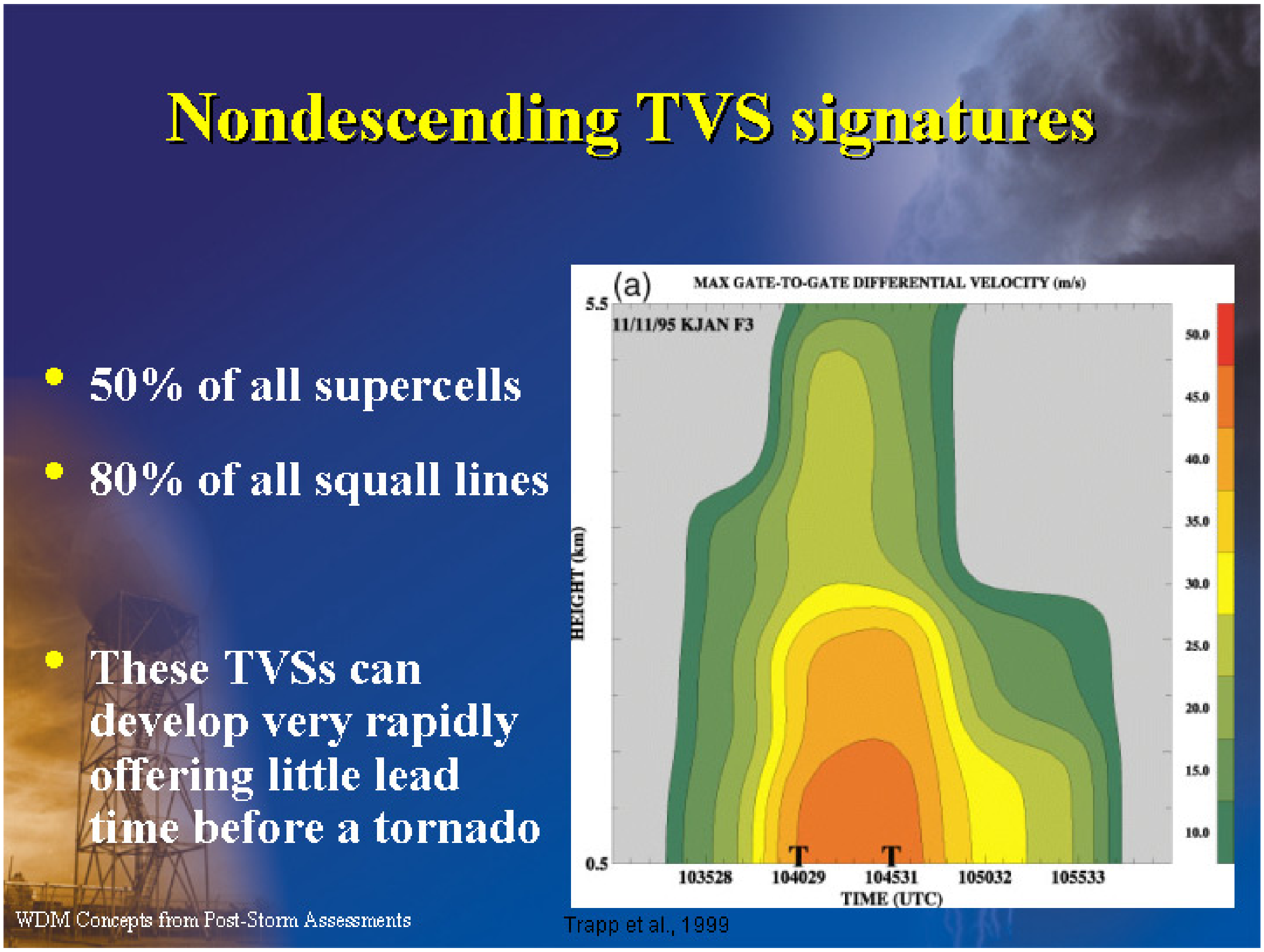


Let's talk a little bit more about TVS's. Exactly what is a TVS? Well it is actually really a mesocyclone at low levels, especially at low levels, because that's one of the requirements for a TVS is that it is visible at least on the half degree angle of the radar, or within 600meters of the ground. A TVS is actually a mesocyclone contained inside the wrapping rear-flank downdraft and the wrapping rear-flank downdraft is represented by the dry slot in the hook echo in most cases. And here on the radar this is where the hook echo is. That's typically where the rear-flank downdraft is too. So inside of that is where low-level rotation is starting to spin up and intensifies so you get a very strong velocity signature here. But as you can see, it certainly isn't anywhere near where the tornado scale is because there's the point of the tornado down here, almost a factor of 10 smaller than the parent rotation of the TVS.

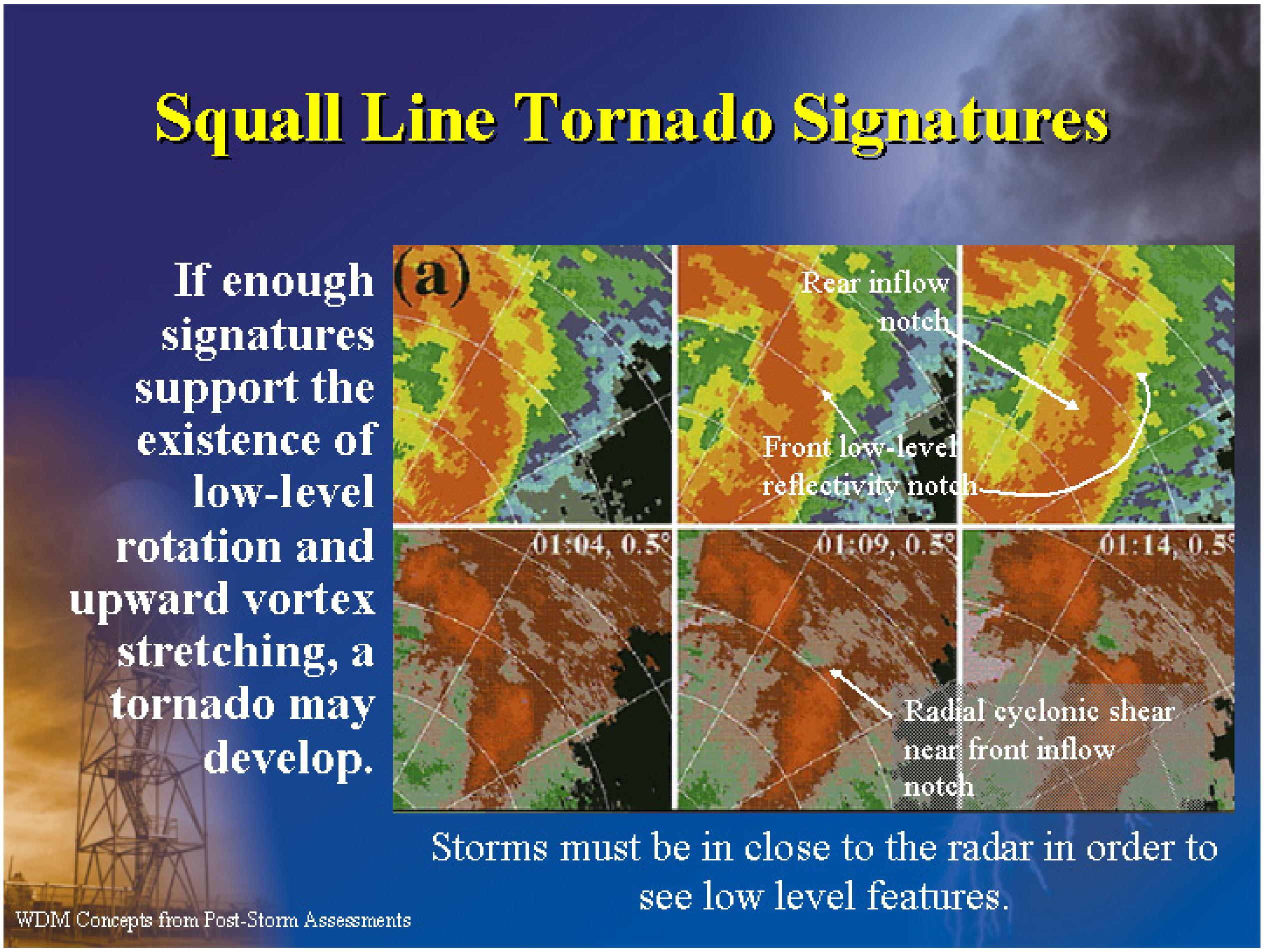


TVS's sometimes actually start at mid altitudes and then descend with time. Now this is as viewed by radar. So this part of the TVS, in this region, is really actually an elevated TVS. It may not be contained within the wrapping rear flank gust front, but the thing is that you start seeing strong velocity gradients, or let's say gate-to-gate azimuthal shear, up at higher altitudes. And then over time it starts descending. This represents a condition that occurs with about half of the observed supercells we've seen and of course it represents the optimistically greater lead time here. In this example time-height diagram here made by Trapp, et al., 1999, you see that you probably could get about 20 minutes lead time between the initial onset of the elevated TVS and then finally the development of the low-level TVS before tornadogenesis.

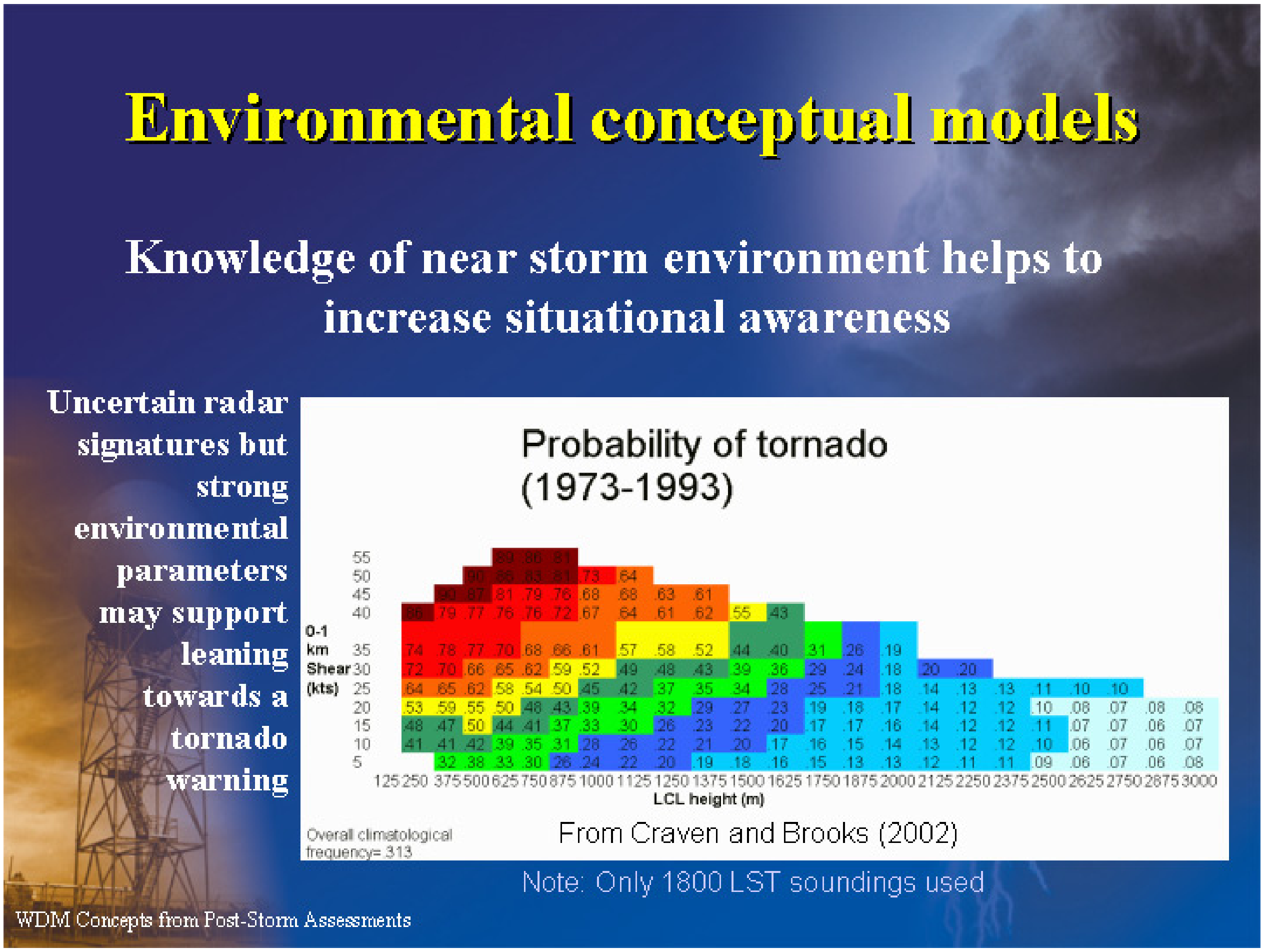
(Trapp, R. J., E. D. Mitchell, G. A. Tipton, D. W. Effertz, A. I. Watson, D. L. Andra, M. A. Magsig, 1999: Descending and Nondescending Tornadic Vortex Signatures Detected by WSR-88Ds. Weather and Forecasting: Vol. 14, No. 5, pp. 625–639.)



More recently though, we've found that half of the other supercells, and even most of the squall lines, produce this kind of time-height signature of a TVS. Essentially, we call this a non-descending TVS paradigm. So the TVS or the strong gate-to-gate velocity signatures start either at all altitudes at the same time, or start low and build up with height, and then intensifies over time. This represents a problem because it is less likely that a distant radar is going to be able to see a signature before it's too late, and also where do you cut the threshold here. At some point, you'll have to cut the threshold before issuing the tornado warning. In other words, if you set the threshold at 25 ms-1 and you issue your tornado warning here, with a few minutes lead time. But if you wait til 30 or 35 ms-1, you might not have any lead time whatsoever. So this represents a little bit more of a difficult scenario on here and unfortunately the majority of all storms runs through this kind of paradigm.



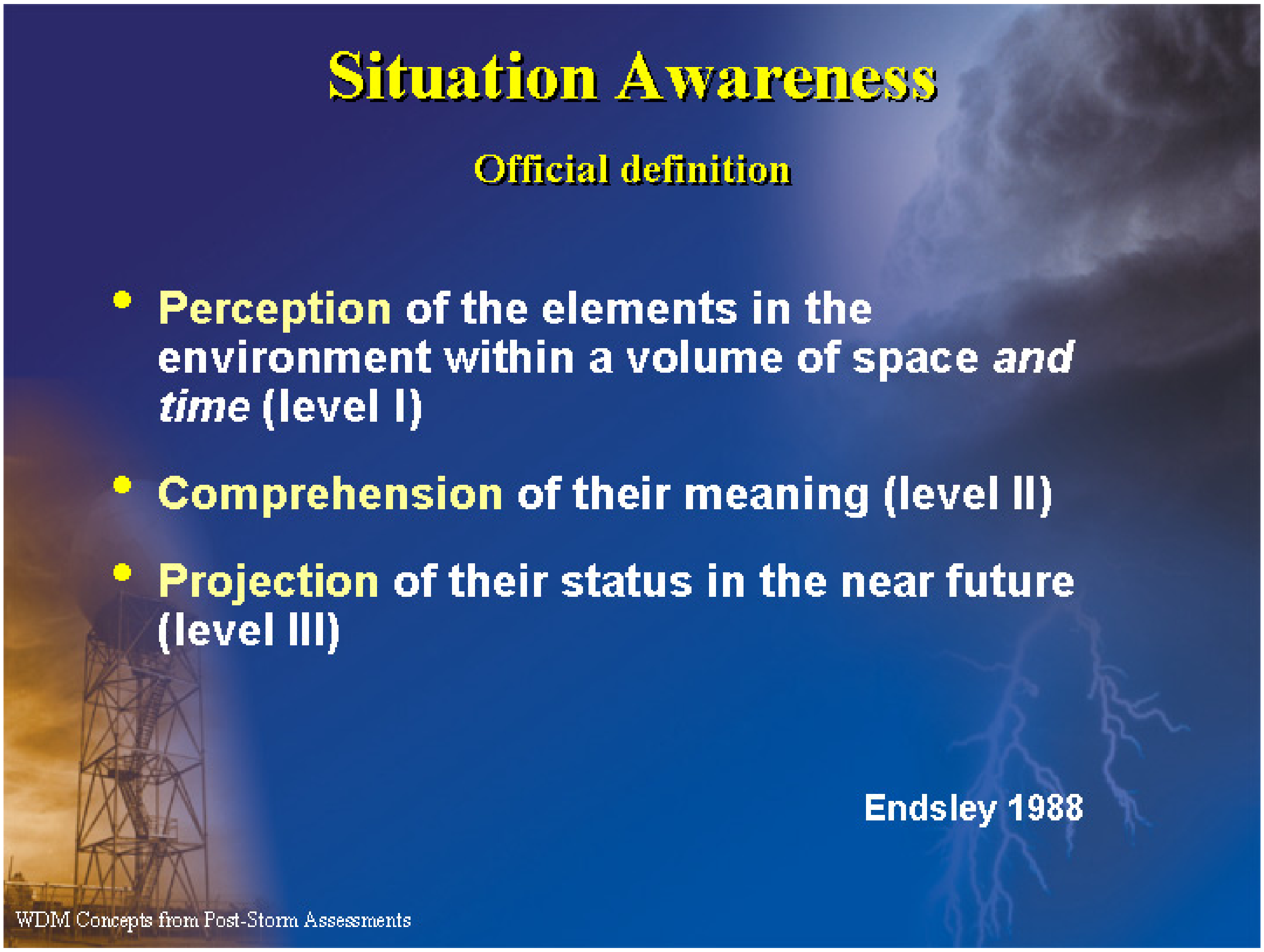
Recognizing squall line tornado signatures is a lot more problematic than that of supercells and the reason is that there just hasn't been that much research done on squall line tornadogenesis. But let's try to remember the original ingredients for tornadogenesis. One is a strong updraft, especially in the low levels, and then secondarily is a source of low-level rotation, whether that comes from low-level mesocyclogenesis or from tilting, or by pre-existing vertical vorticity, it doesn't matter. But the key is that you can detect that using the radar. So reflectivity structure, a strong updraft. Well, just like with supercells, a strong updraft is represented by an inflow notch on the inflow side with a very sharp reflectivity gradient. Maybe there's a weak echo region overlying, there's a heavy core creating a weak echo region on top of that inflow notch. That's a good indication that there's a locally intense updraft here along the leading edge of this line. Another favorable signature we've often seen is that there's a local region where there's a rear inflow notch, indicating an enhanced outflow aimed right at the front and to the right of that inflow notch. Both of those indicate we have a strong updraft and a suggestion that we could get or develop shear along the leading edge of the gust front. And as it so happens down here, you can see in the velocity, strong outbounds to the right of the inflow notch and zero outbounds or even some weak inbounds coming in at the inflow notch point and very strong shear right along that interface there, so there's actually kind of a weak mesocyclone. This is a region to look for tornadoes.



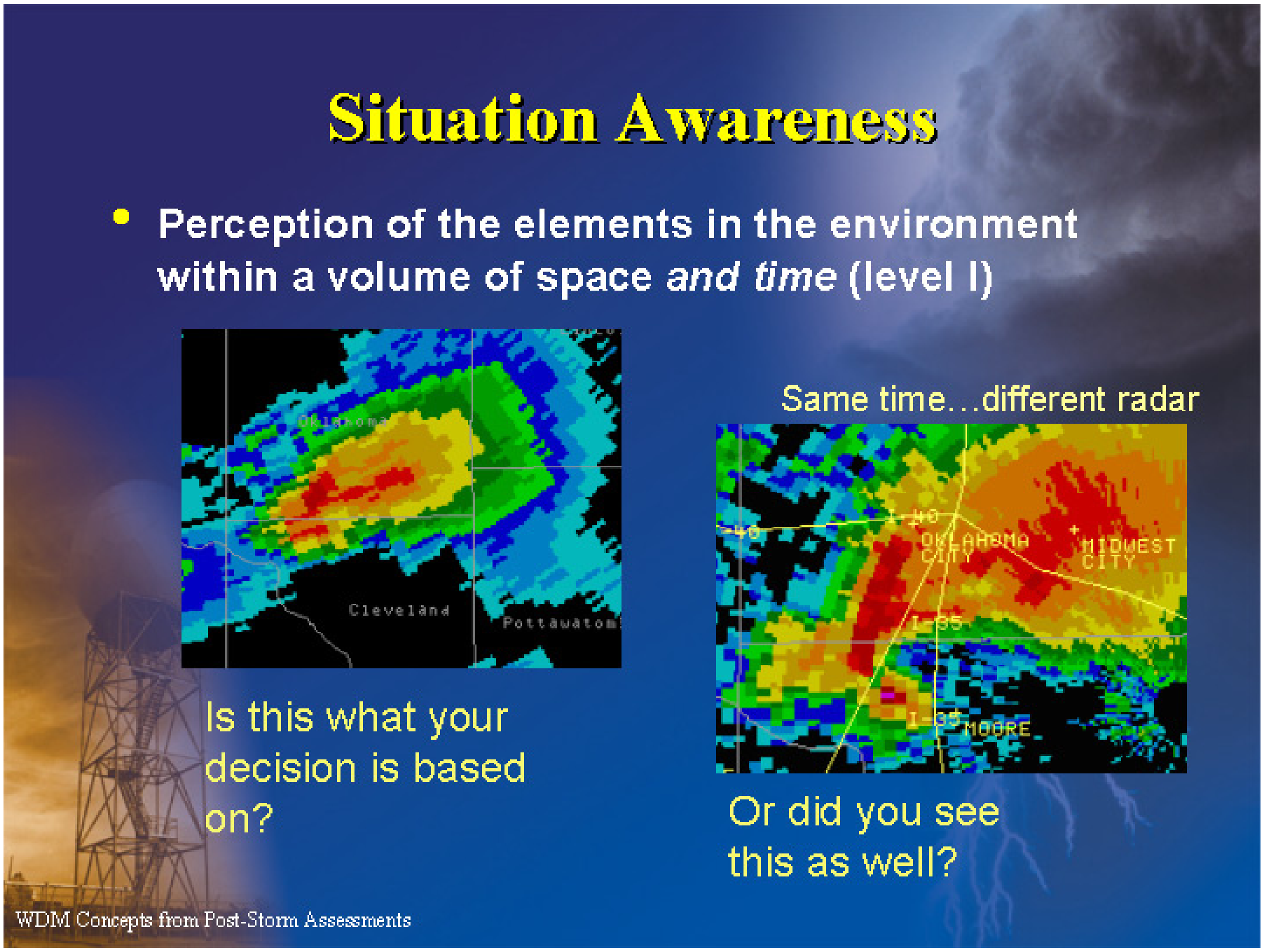
It's very important to remember what the environment is like when you're in a warning situation. For example, what if you had a TVS with a gate-to-gate velocity difference of 15 ms-1. Maybe you're about 60 miles away from the radar. If that TVS exists in an environment where you have very strong low-level shear and low LCL's, you might be more inclined to issue a tornado warning in this kind of situation, even though the low-level delta V is not very high, and maybe the other storm characteristics are not very strong. But with a real favorable environment, then the situation might put you towards tornado warning. So always look at the environment and see what's going on. It might help you decide what to do with a questionable signature.

(Craven, Jeffrey P., Ryan E. Jewell, Harold E. Brooks, 2002: Comparison between Observed Convective Cloud-Base Heights and Lifting Condensation Level for Two Different Lifted Parcels. Weather and Forecasting: Vol. 17, No. 4, pp. 885–890.)

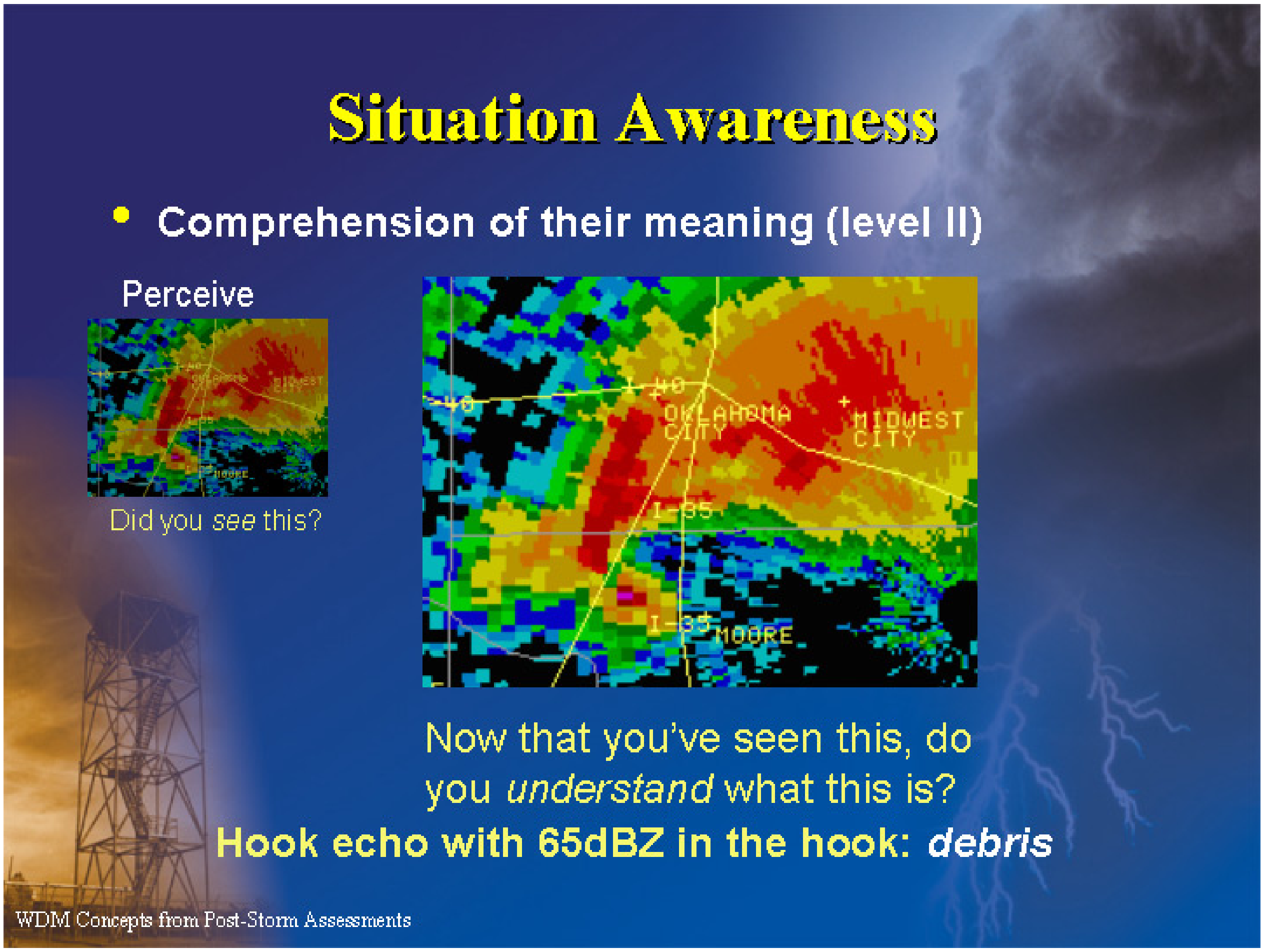
One of the other topics we would like to review for you in this session is the topic of situational awareness and you can think of it as just your ability to keep the big picture, maintain the big picture. It is very important in deciding what course of action to take next and the course of action being taken by these gentlemen in this large delivery truck is determined by their SA. You have the co-pilot in this truck, telling Harry to watch out, the truck is way over 4 meters high and of course Harry is only worried about whether the cops are present or not. Can you talk among yourselves and decide which one of these guys had good SA. And if you chose this guy, you are doing pretty good.



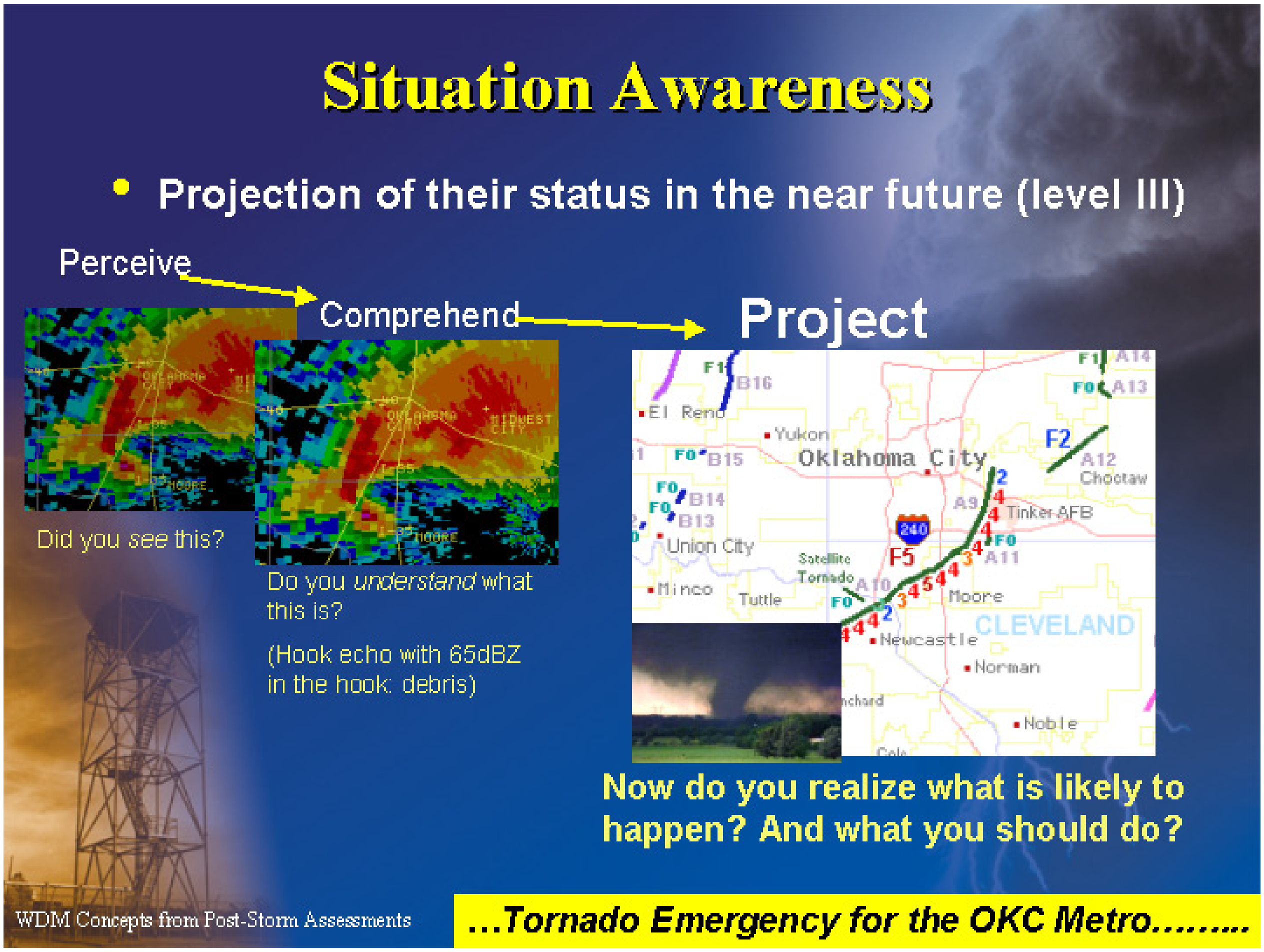
Officially, the definition of situation awareness has three parts and this is from Micah Endsley, who is sort of the "mother of situation awareness" you could think of. The three parts are perception, seeing the information, is it available, is it in front of you, do you have access to it. Comprehension, which is understanding what those things mean. Level three, which is projection, which is now going, okay, what does it mean I do with that in the future, what is going to happen, what do I need to do because of that. Perceive, Comprehend, Project. The three levels. In doing a forecast or doing a warning, requires all three levels of situation awareness.



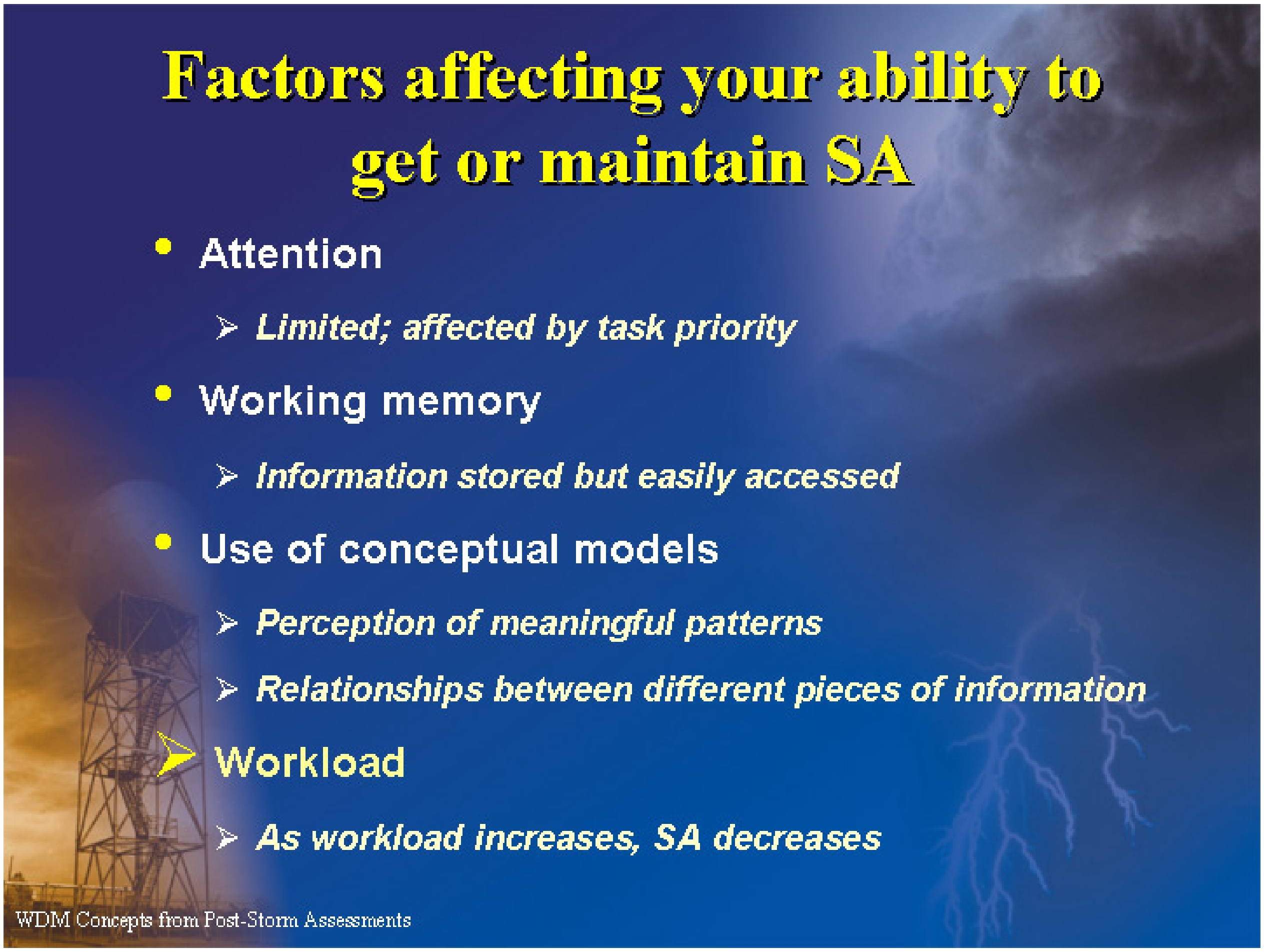
So let's look at this in terms of a warning event, let's say. Perception, merely seeing the information, how can you make a judgment on anything if you first don't see it. Get it in front of your eyes or near your ears, or something. We are looking at two pieces of information, radar data. One is from a radar that is 70 or 80 miles away and at the same time with a different radar we have a different picture. What is your decision based on each of these and what happens is you only see the one on the left. You are probably going to have some indications of what is going on, but you will certainly now have an indication that there is this nice hook echo with a large reflectivity return at the center of the hook. If you don't give yourself the opportunity to see the most relevant information, then your failure in Level 1 is going to be a problem.



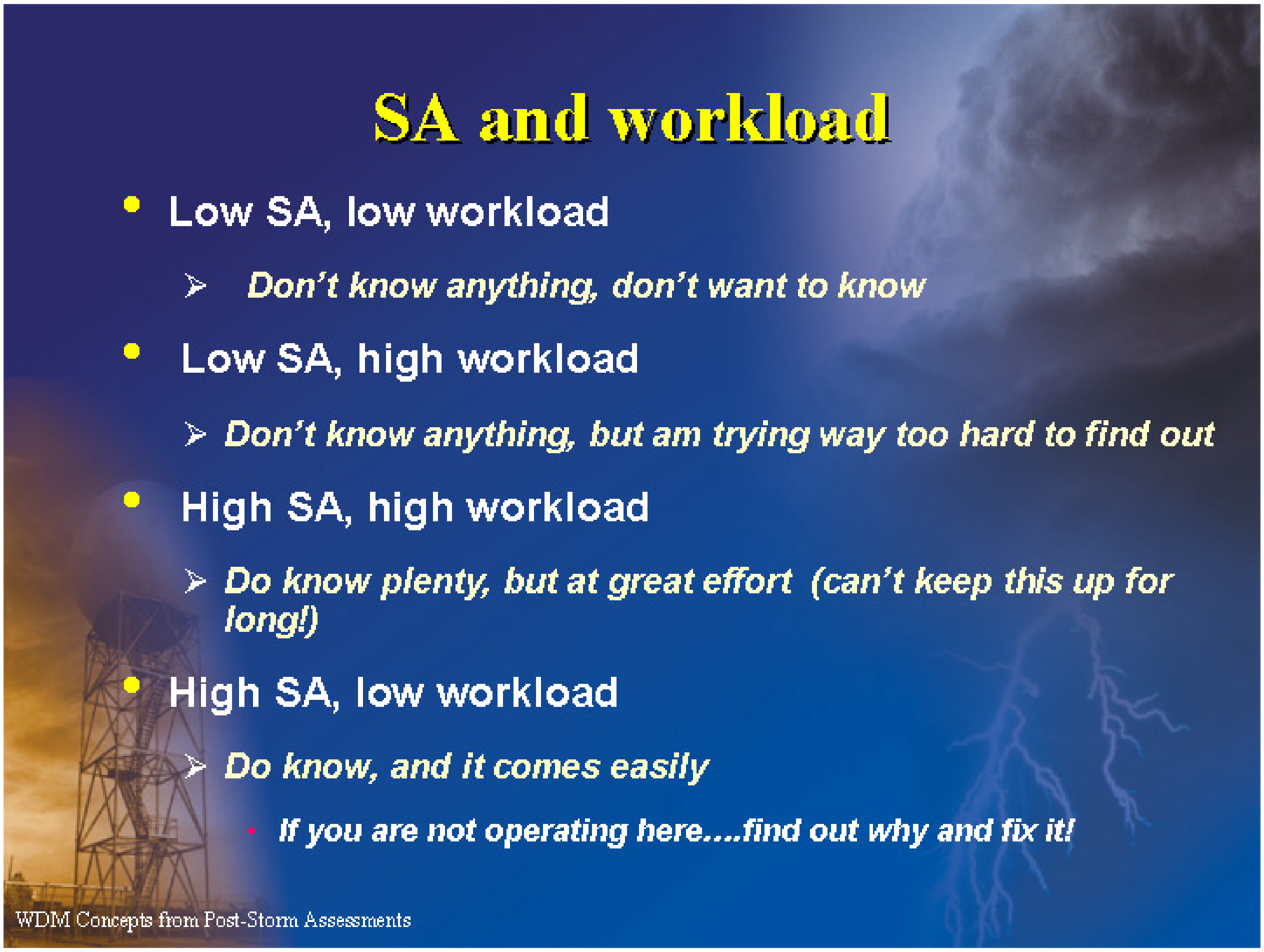
So it is not enough to see the information or hear it, you have to comprehend what it means. Okay, let's assume that we did get to see this nice feature, this nice radar image, do we understand what that is. The average person probably has no idea what they are looking at, but you are not the average person. You look at this, you understand that you have a hook echo. Do you also, understand that you have return of 65-70 DZBs in that echo, do you understand that that is caused by debris. That is a very important piece of information and understanding that there is debris lofted in that return and causing that should lead to your next step which is Projection.



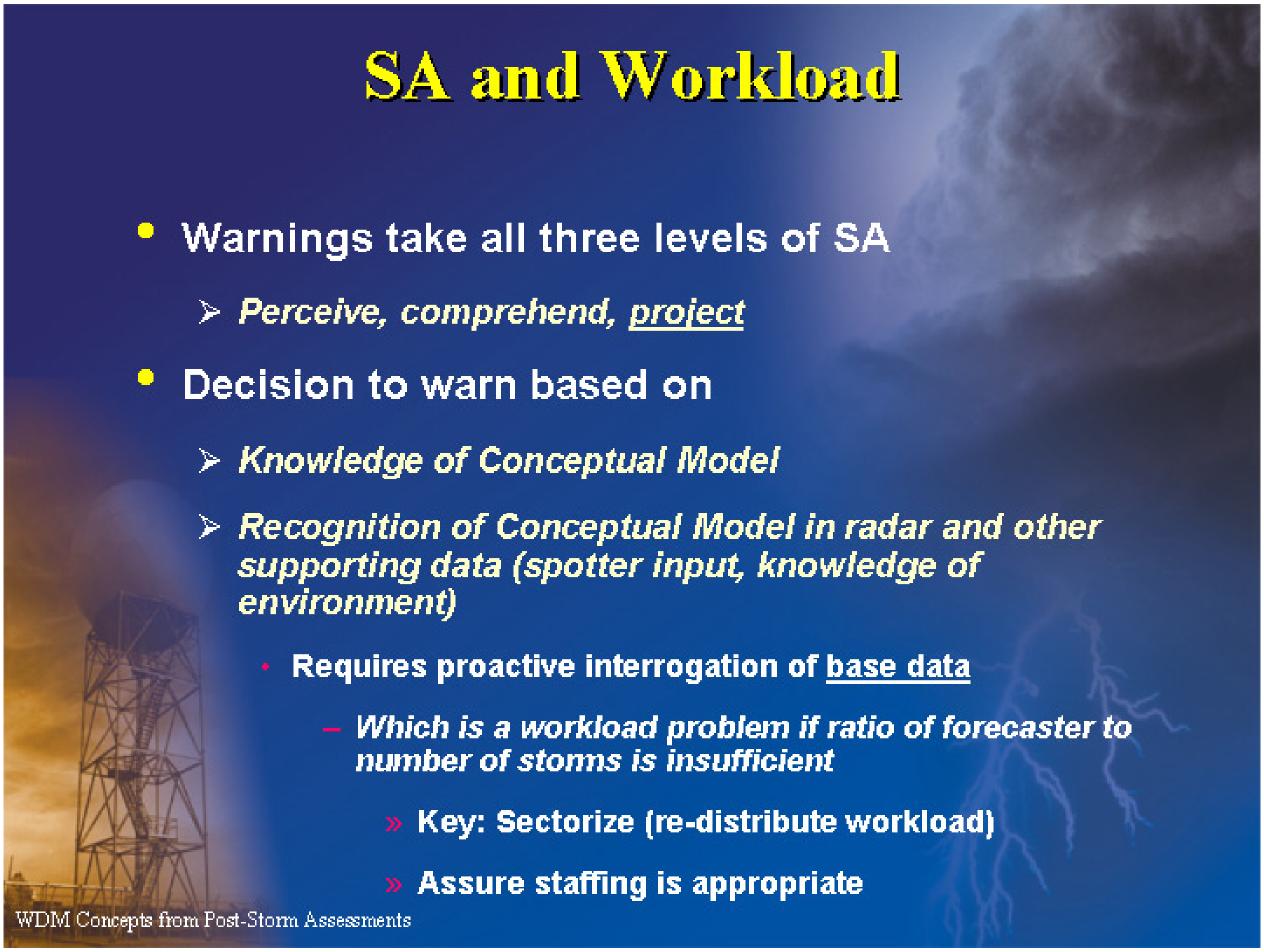
So I saw this great radar imagery. I understand that it is a hook echo and its got reflectivity so strong that I associate that with debris and in my mind, that might mean, I've got what I thought was a radar indicated tornado. Instead now, I have pretty much in my mind, confirmation that there is a tornado, and something has been hit and there is debris being lofted. So, if I take that and project it into the future, do I conclude that I have got confirmation that I have a tornado moving into a large metro area and should I have those two things together, what should I do with that. And if I think it is something catastrophic and I am convinced of that, I probably would do something like a tornado emergency. That was a Level Three situation awareness decision. I saw the information, I understood it, I projected disaster in the near future, therefore my actions were based on that projection.



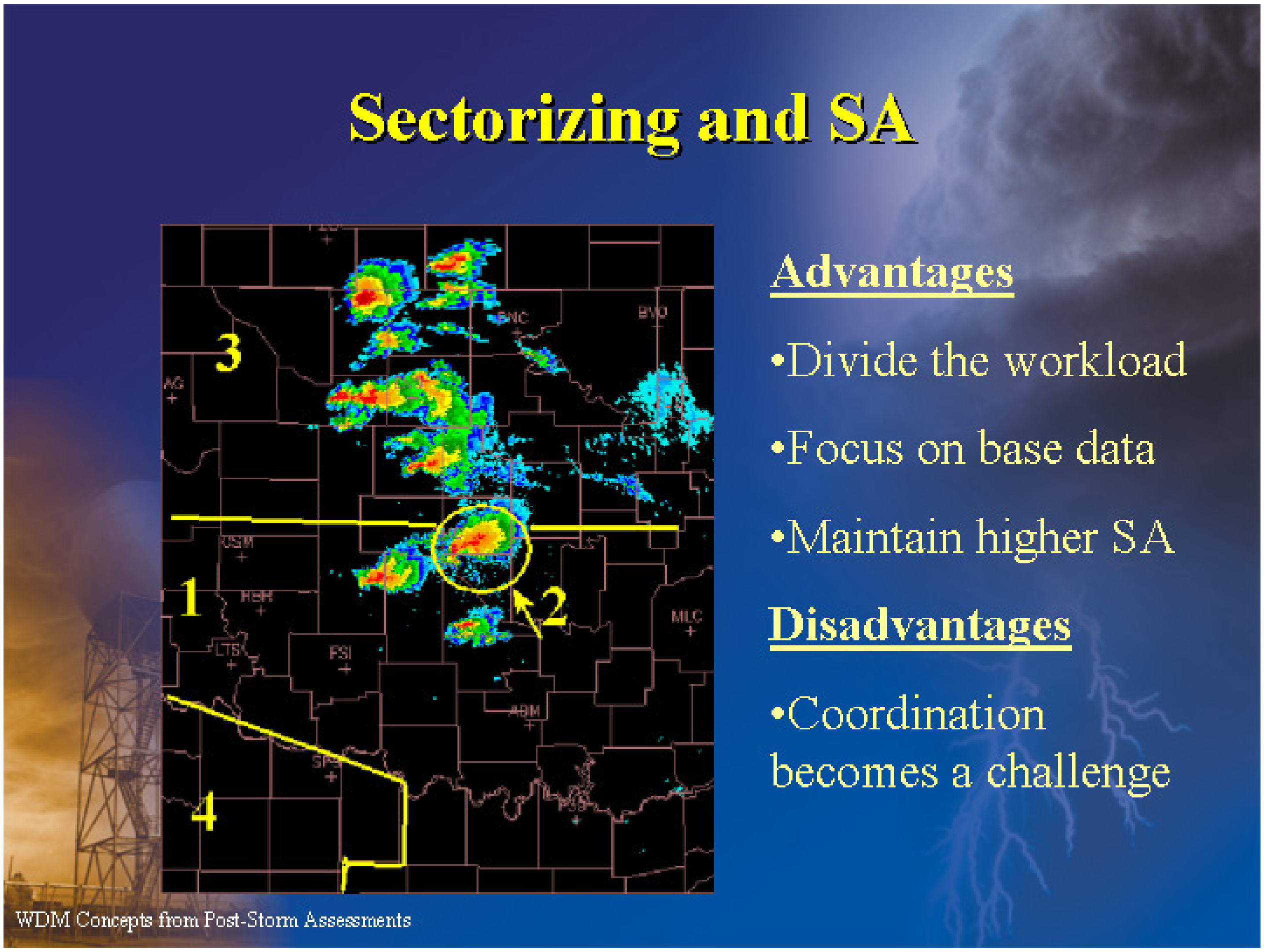
So how do you get SA? Are you born with it or what. Contrary to popular belief, it is not something that you either have or don't have, it is something you acquire. And the things that impact your ability to get SA is how much attention you have to devote to whatever task you are doing. If you are doing way too much, you are probably not spending enough time on one task or another. Working memory, stuff that you have in your head that you can easily access. Your use of conceptual models, which makes sort of order out of chaos. You get to reconfigure meaningful patterns because these things are in place in your head and you can put relationships with different pieces of information together. The one I will spend a little bit more time on is workload, because as your workload increases, your situation awareness is going to decrease and that is something we can have an impact on.



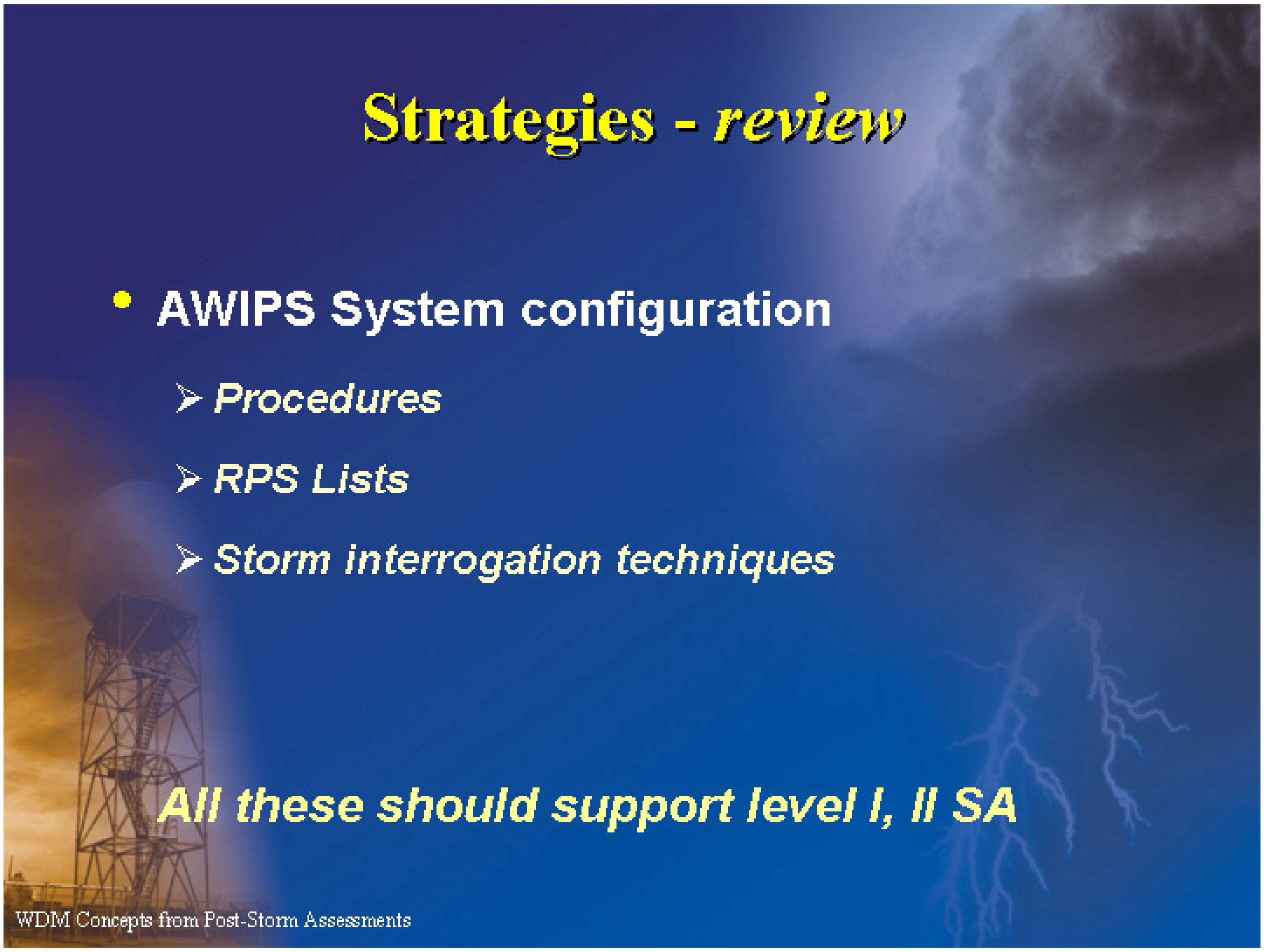
There are basically four states of situation awareness and workload. And I want to think about your careers and your paths and maybe you picture somebody who would fit in each one of these states. Hopefully, we all fit into one in particular. Low situation awareness, low workload. This is someone who doesn't really know what is going on and they really doesn't want to know. They are kind of flowing along pretty smooth and pretty easy and they are actually kind of easy to work with but they are totally obviously to what is happening and not doing anything to find out. Moving a little bit up the scale is the person who that has low SA and but they are trying to do something about it. This is a scary place to be, because this person knows they are behind the power curve and they are trying their best to do anything they can to find out, maybe all the calls they are making are having no response, they are having equipment problems and they cannot display the procedures that they want to display, the radar is not working, or they can't get additional input perhaps, from another radar view. They know they don't have the big picture, they are trying to get it. A little bit better, is the person that has a good situation awareness but it has taken a lot of work to get there. And they can operate this way for awhile but eventually, it will wear them out and things will start to fail. This is really where we want to be, we've got situation awareness and it comes easily. Data is flowing well, we have good strategies, good configurations, our spotters are well trained, they're in the right place, it is good visibility, equipment is performing flawlessly, we have enough staff, they are trained, their workload matches what they are able to do. This is where we want to operate and if we are not there, we should look at the reasons we're not and try to make adjustments.



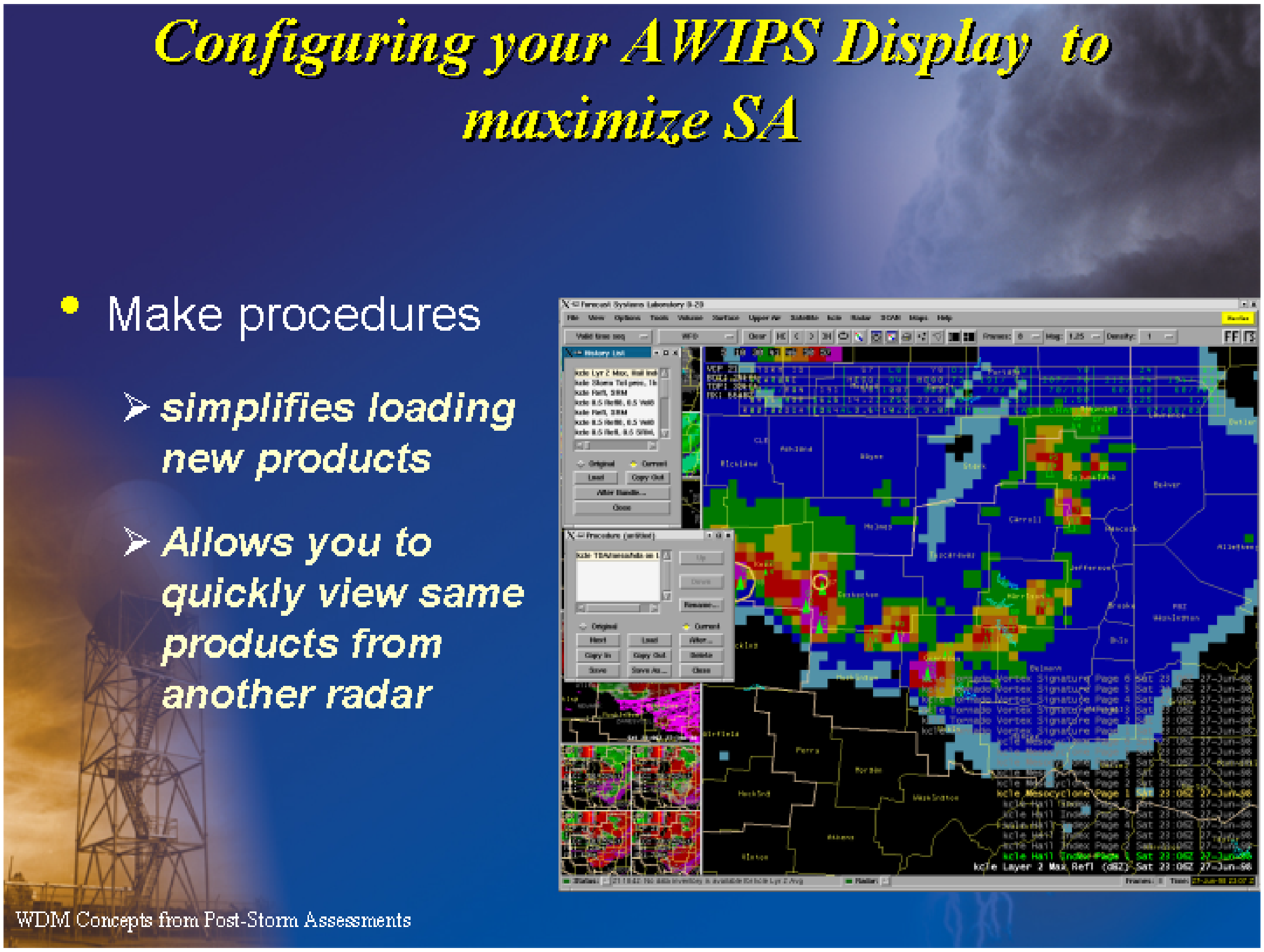
Ultimately, issuing warnings will take all three levels of situation awareness. We have to perceive the threat, we have to comprehend what it means, and project what's going to happen in the next hour or so. Our decision to warn is based on what we know of conceptual models, our ability to see those and apply them in real time. This requires us to do a lot of base data interrogation. Conceptual models are recognized in the base data as well as in analysis of the environment. This is a workload problem, and if the ratio to forecaster with number of storms is not working, then there's going to be a problem here. One of things that will help decrease workload and redistribute workload is resectorizing, but requires appropriate staffing and the ability to coordinate.



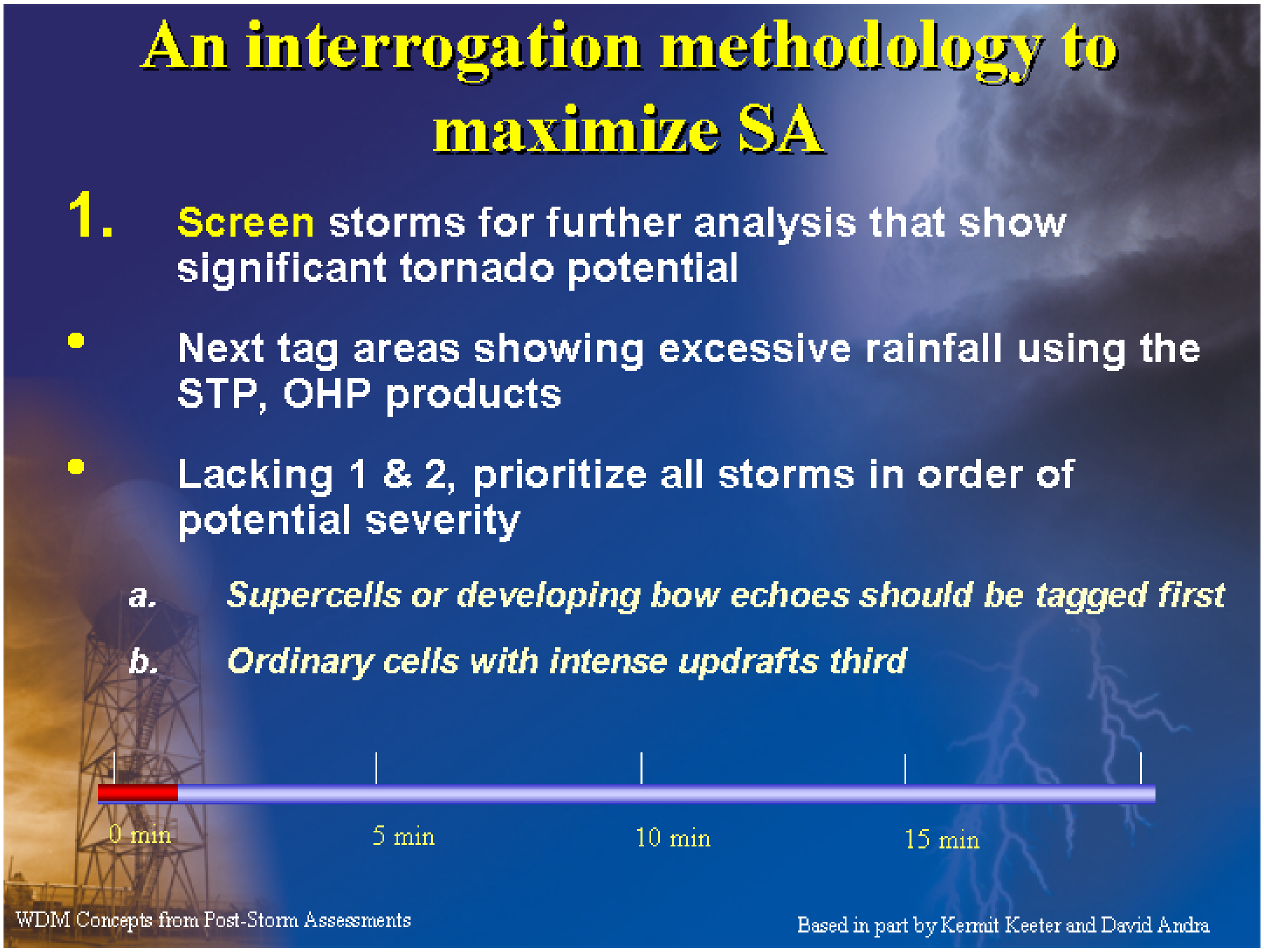
Some of the great advantages of sectorizing include dividing the workload which allows us to focus on the base data which helps us maintain a higher SA. Some of the disadvantages, now, occur, because coordination is a challenge where I didn't have to coordinate before. This sectorizing is much like what air traffic control does, when planes move across the U.S. and go in and out of sectors. There is coordination which occurs across those sector boundaries. This is an illustration, at one point in time, was the sectorizing scheme on May 3rd for the Norman office. And you can see in this case, one person had, at least for awhile, sole responsibility for the storm moving through the Oklahoma City metro area and that allowed them to provide much more information and statements to the public and to the media, instead of having to focus on several storms and perhaps not giving as much detail for each.



To maximize your situational awareness in a severe warning environment, I will be talking about some things you can do with AWIPS to help you become more efficient. AWIPS comes with lots of things to help you become more efficient like procedures, RPS lists and other ways to help you interrogate storms in a more efficient manner. Now this is the section I'll spend most of my time on because this is the area where you can get easily bogged down, especially if you face a situation that you don't normally see in your CWA.

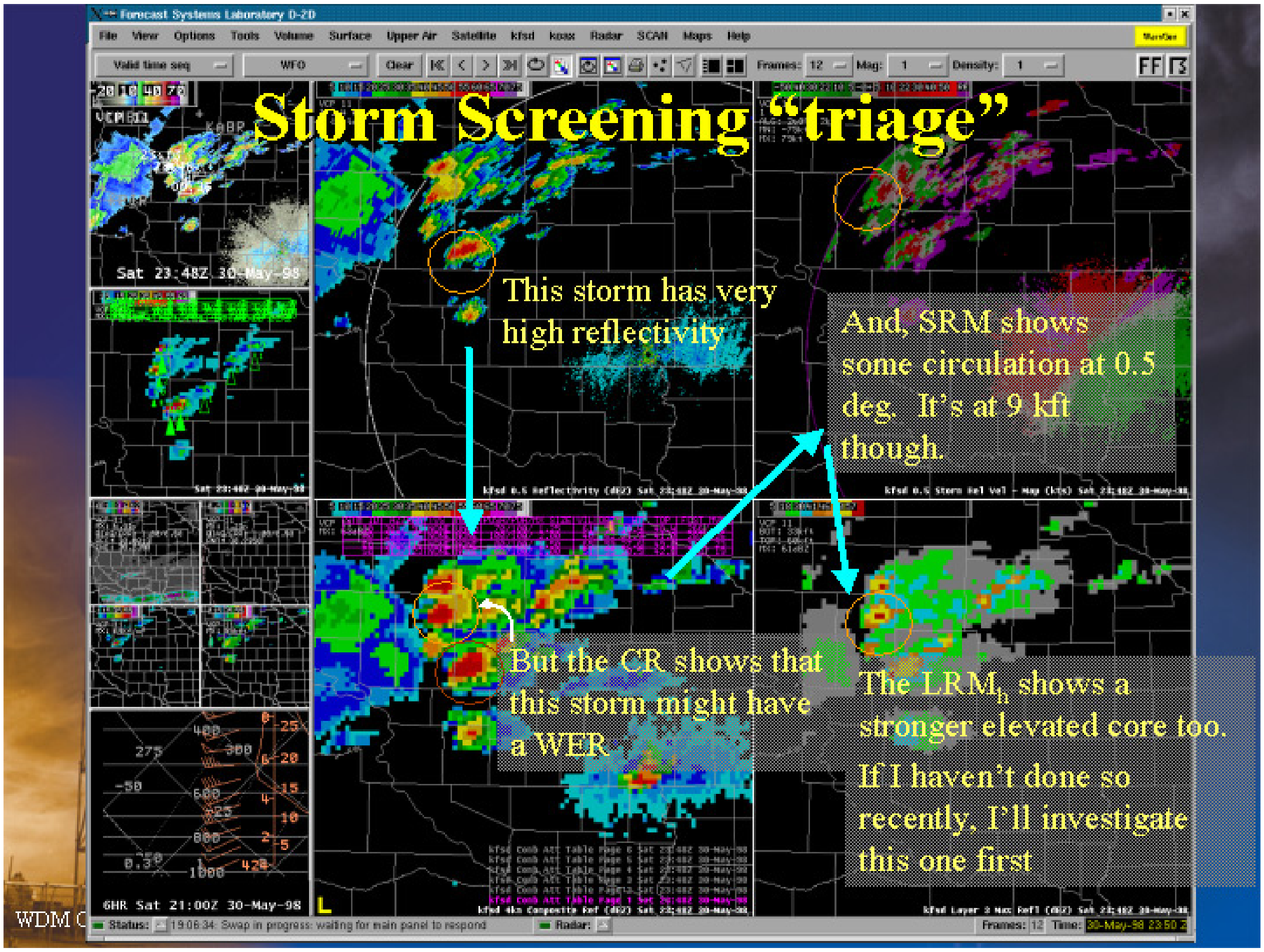


Personally speaking, I'm not a computer-savvy person that can flash through a bunch of functions and and get a map that I want in a matter of a few seconds. It takes me time. For example here I got a map example with yellow borders, yellow county names, blue lakes, roads and all overlaid by LRM, meso TVS and hail. It takes me 2min to pull all this together. Can you imagine a situation where you have to do that especially after an AWIPS hang and you're in a warning situation where you should be looking at storm structure instead of figuring out the display. So, please remember that if you don't have a sufficient types or numbers of procedures or are a little rusty on making them, familiarize yourself with them before the convective season begins.



Let's go ahead and talk about an interrogation methodology that can maximize your situational awareness. This is not the only one out there but if you're a bit rusty or you don't experience a large number of events, try this one out. We're going to go ahead and start off with a method that is a combination of methods between Kermit Keeter, the SOO in Raleigh, NC and Dave Andra, the SOO at Norman, OK.

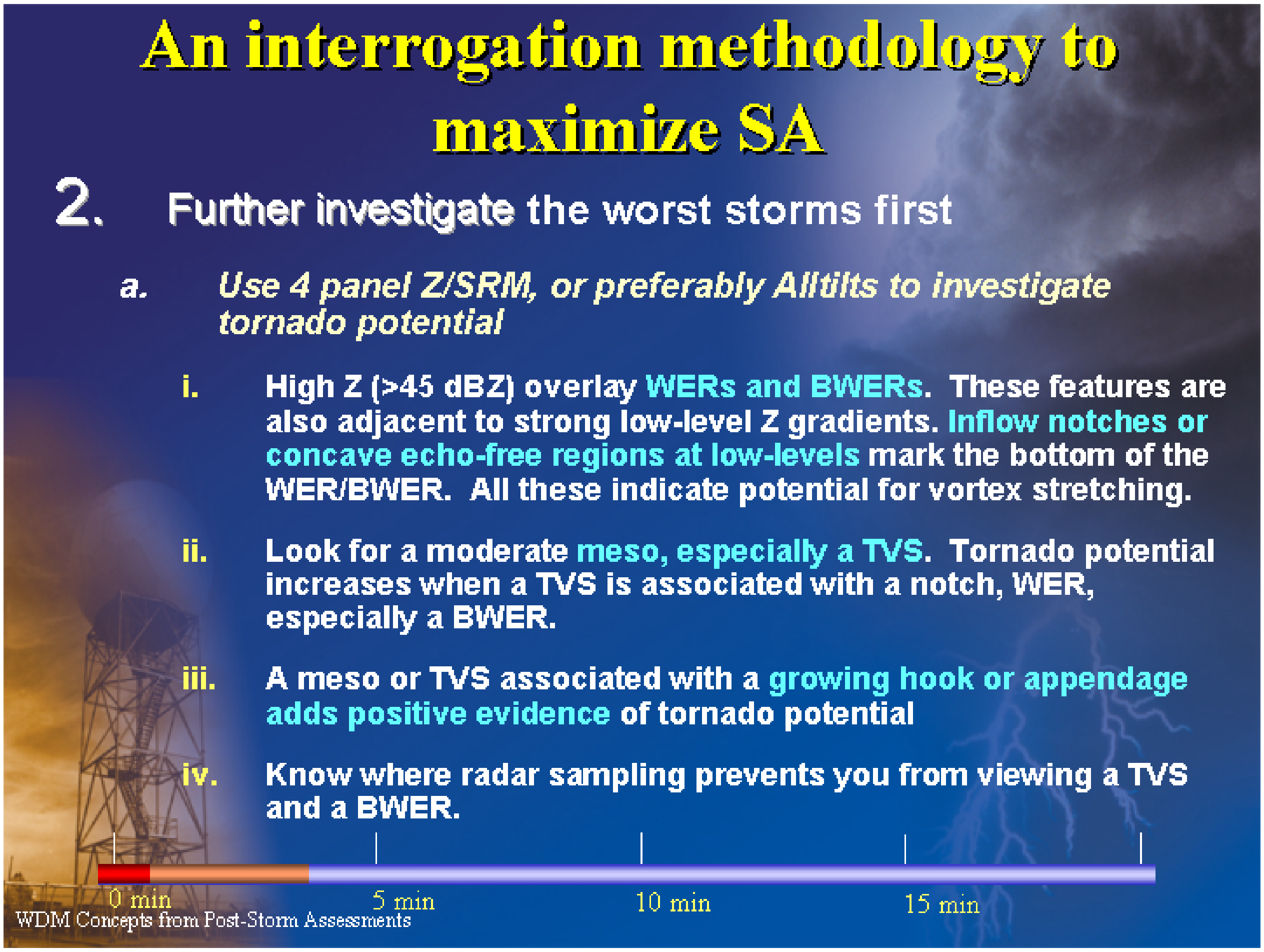
Let's go ahead and start out here. I have a timeline down on the bottom that highlights a suggested amount of time that we should be looking at various parts of this methodology. I think what we'll do is take a look at the big picture first. We'll call it 'Screen All Storms' after Kermit Keeter's methodology. So we're gonna look at the entire county warning area and look at all the storms and look at a few products that tag the storms with the greatest tornado potential first, then the greatest rainfall potential and then the ones that are most likely to produce severe winds and hail.



Just like in a medical emergency where you have a triage room where doctors scan the worst off patients first and then prioritize the rest of the patients according to the severity of their injuries. We'll be doing the same thing here. We'll be using a 4 panel as shown here (although you don't have to pick the same products as we have - these work very nicely).

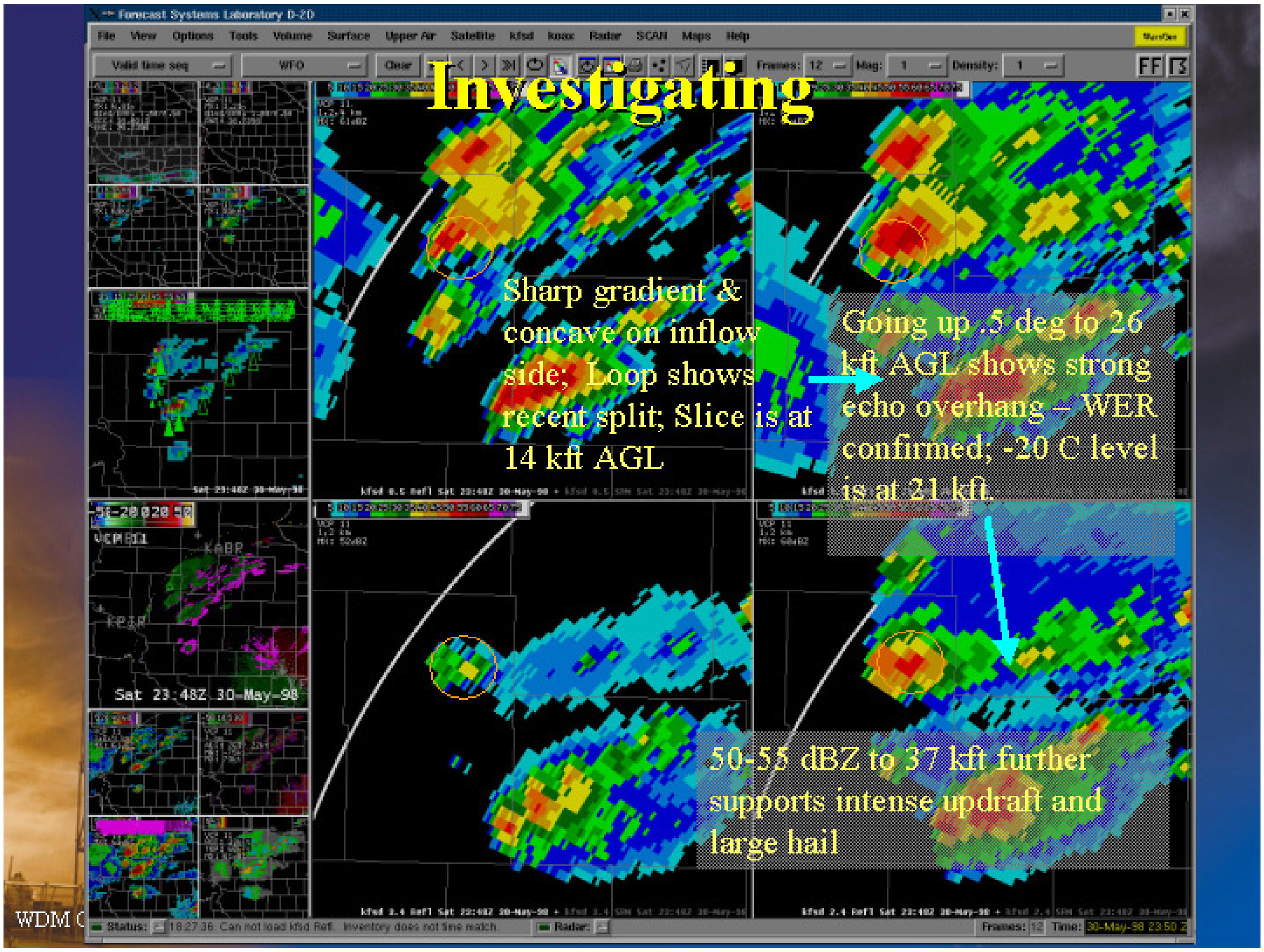
I'm going to pick the storms with the greatest tornadic potential first so I'm going to look at a couple storms (upper -left of upper left panel). First, right off the bat, this storm has a really high reflectivity core (orange circle in UL panel) and I see a couple others further northwest but the reflectivity isn't as high. When I go down to my composite reflectivity (lower-left), I find that the initial storm with the highest low-level reflectivity doesn't have any echo over-hang (WER). This one up here does (next storm to the northwest) and I find that the storm to the northwest also has a low-level concave reflectivity region. It's an interesting sign of a better updraft.

Let's look at the SRM (upper-right) and I find that the storm to the northwest has velocity couplet while the storm to the south does not. Down in the lower-right panel, the LRM high product (>33 kft) shows a more intense reflectivity core with the storm carrying the WER and velocity couplet than with the storm to the southeast.

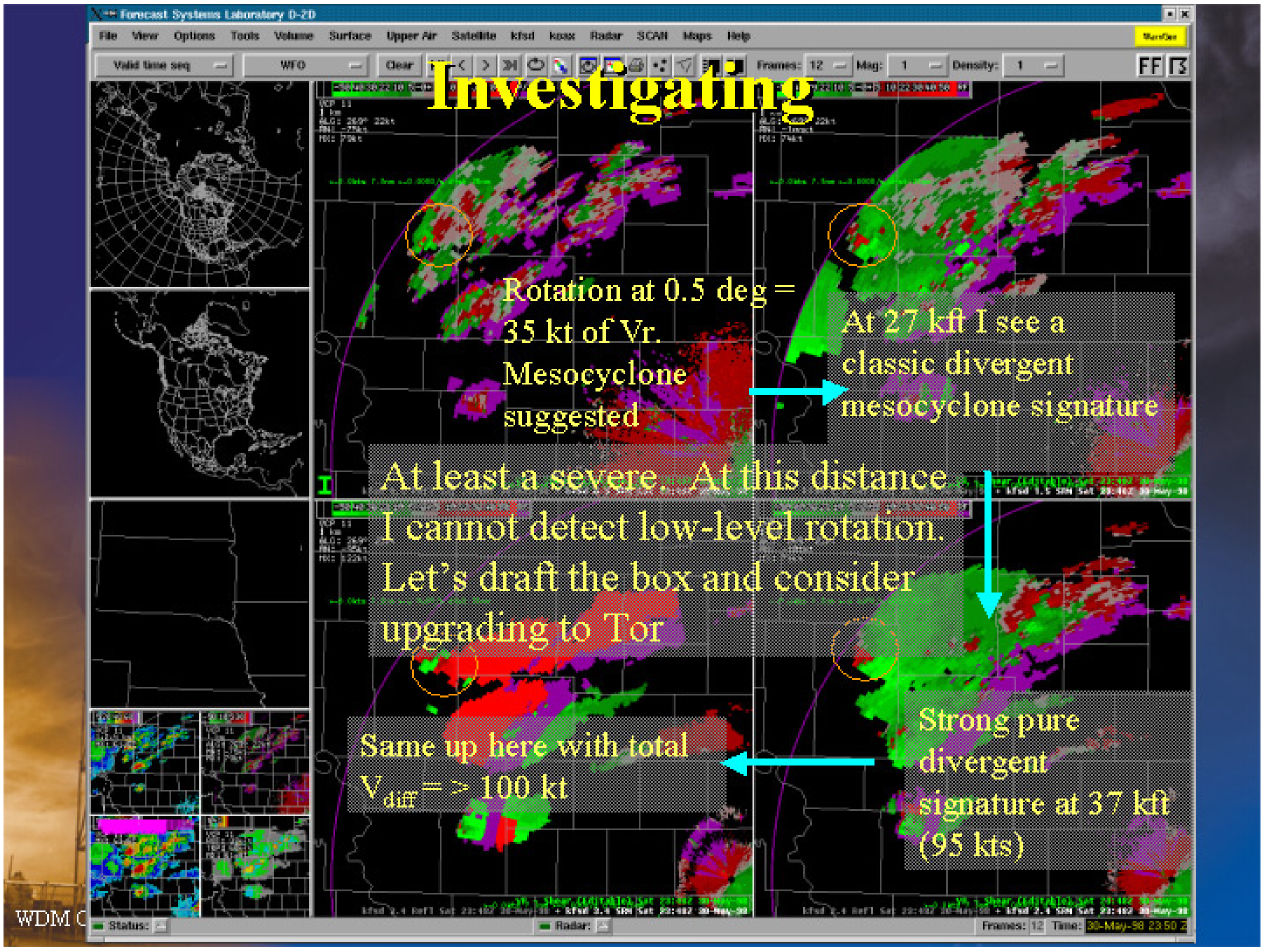


Let's go ahead and look at that storm. We just went through the screening process. We saw which storms we need to pay attention to first and then which ones we could pay attention to later after dealing with the worst storms.

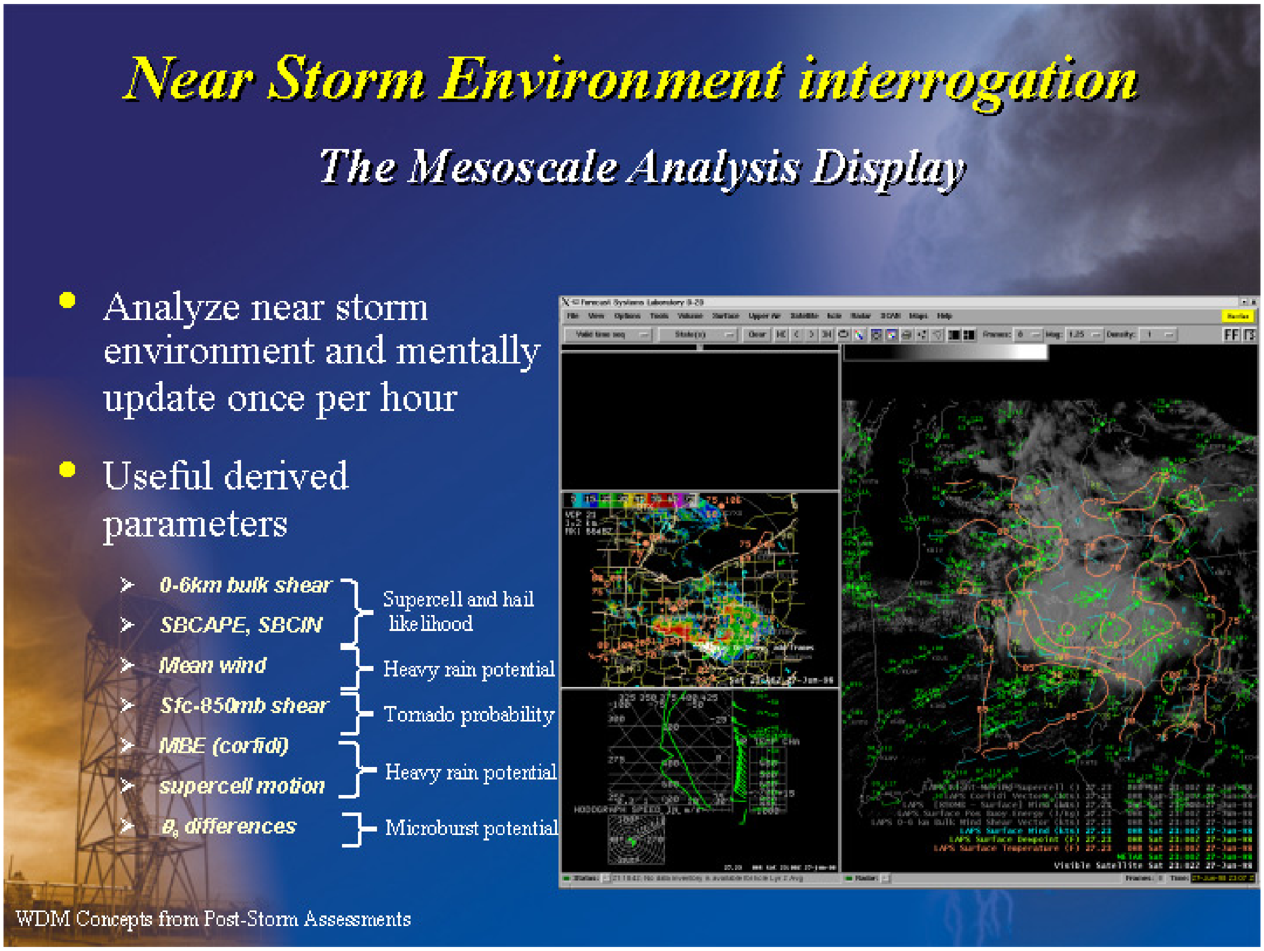
Number two is let's investigate the worst storms first. And now we get into a little more detail using the 4panel reflectivity/SRM or the all-tilts display of each to investigate its tornadic potential. Okay, so here's a couple features that you can use. Remember that we're looking for signatures for tornadic ingredients, strong updraft and strong rotation.



Let's go ahead and investigate this storm in more detail. I'll use a 4 panel. Z/SRM. Notice right away that my 0.5 deg is pretty high and so is my 1.5 deg slice. So I don't have much to work with but let's take a look anyway. My lowest slice shows a sharp Z gradient with a concave structure on the inflow side of the storm in a SR sense. A loop of this (not shown) shows that the storm split and there's the left-mover to its north. Indications are that I have a supercell here. If I go up to 1.5 deg, I'm up at 21 kft. At this elevation, I'd expect to see an elevated core and that is what I do see. At 37 kft, I see 50 55dBZ and that's pretty good. That's a very strong updraft and expecting at least large hail.

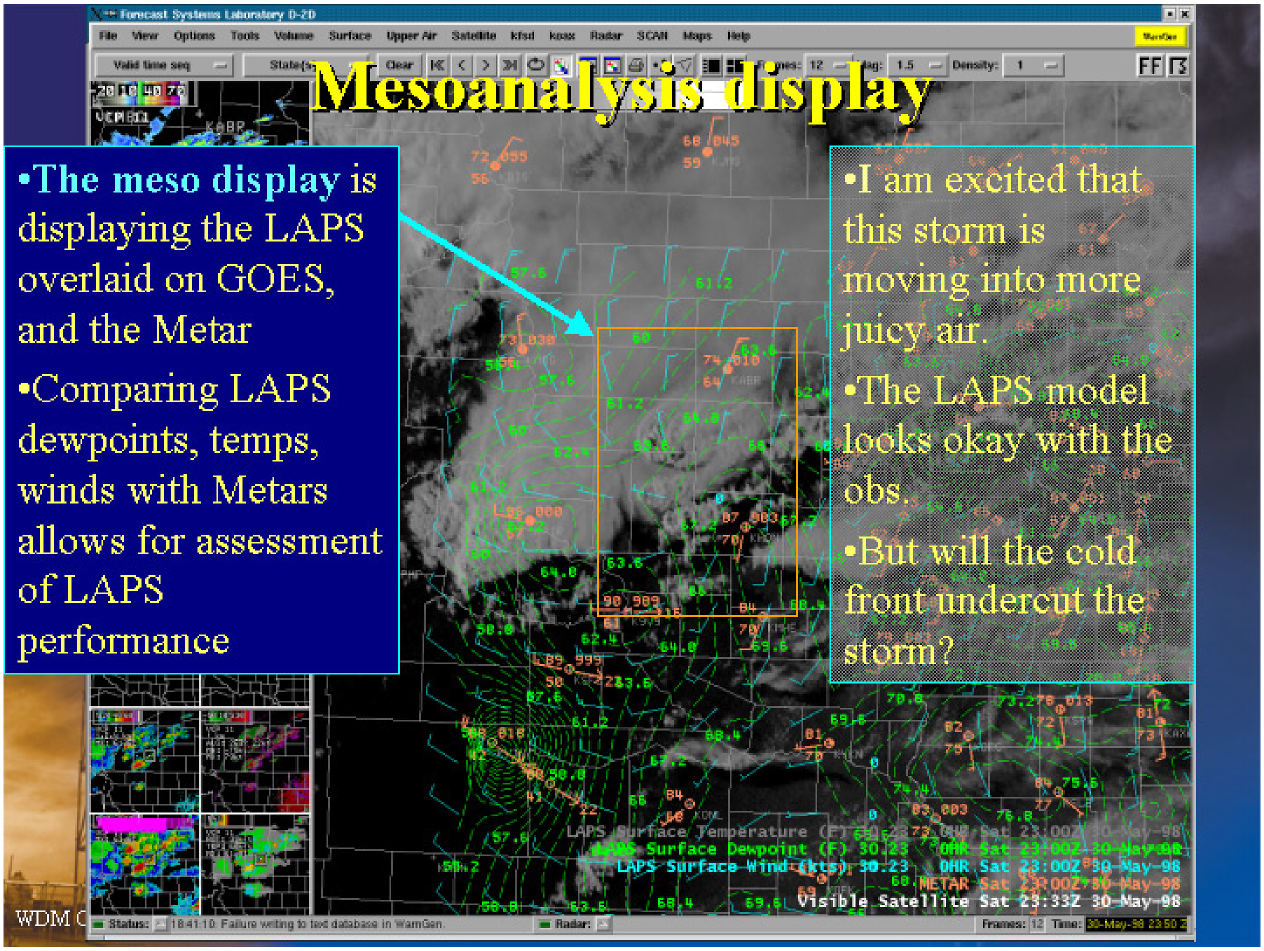


Looking at the SRM, I see rotation at 14 kft. 35 kfts of Vr is pretty good so I know I have a rotating supercell, part of the rotation occupied by updraft. At 27 kft I see divergent rotation. Higher up, I see strong divergence up to 100 kts. So, very strong updraft and at least a severe warning. I haven't decided about a tor but to be on the safe side, I'll draw up a tornado warning box.

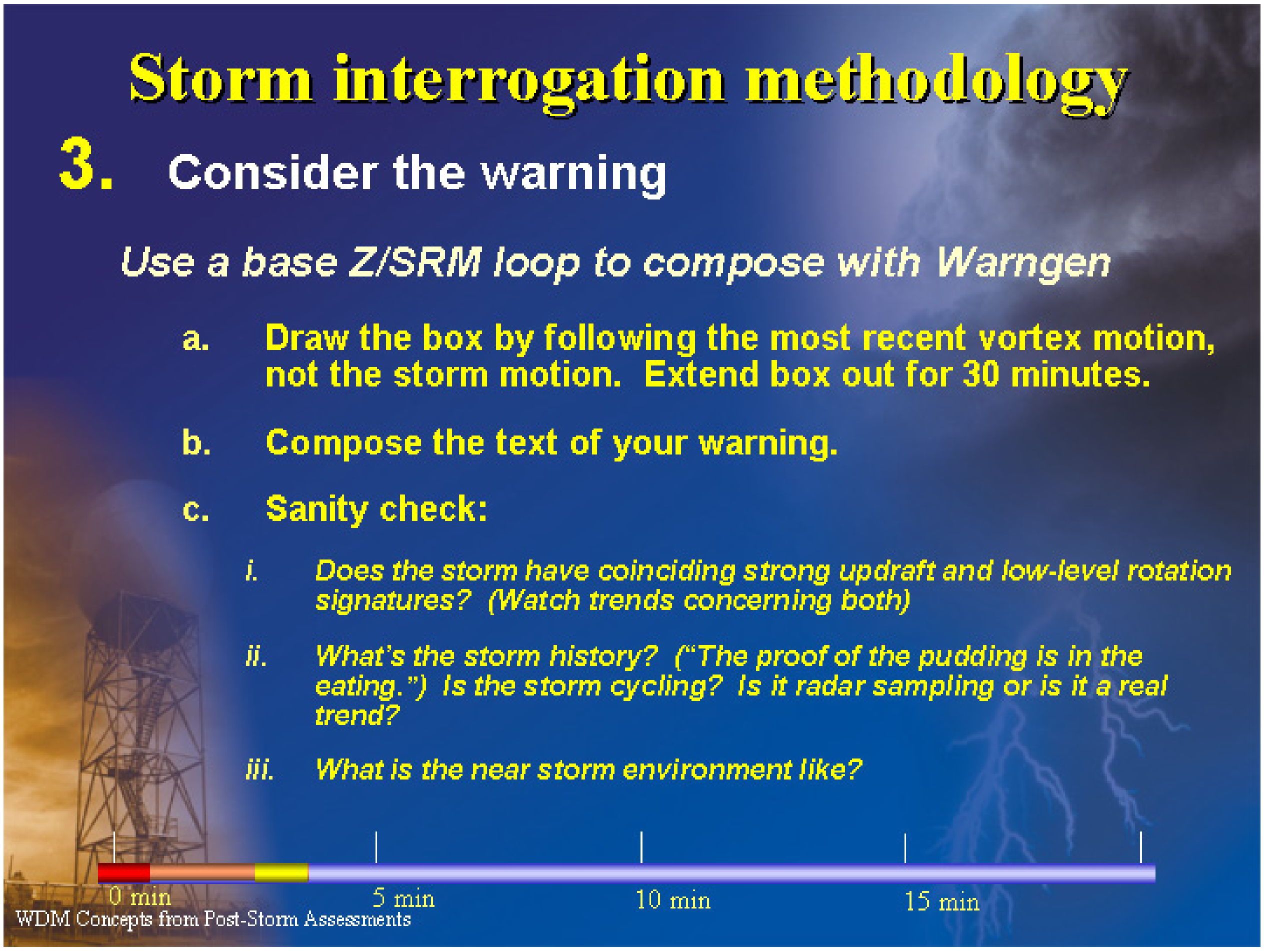


Every hour, doesn't have to be every volume scan, you should take a look at what is your near-storm environment, and so we suggest in addition to your screening, and storm investigation, you should have a mesoscale display. What we suggest is taking a look at plotting your metars upon a satellite or radar image. I prefer satellite because I can see boundaries outside radar range. Sometimes, the opposite is true in case there's high overcast and I cannot see features except by radar.

On the image, I want to put on metars, LAPs data for example or other mesoscale model that has temperature, dewpoint and wind. The reason is I'm going to verify the accuracy of the model by comparing the metars to these laps analysis of these features. You can do that or have help. In addition, I like to put some of these parameters (listed below). I won't talk about these in detail but these are some suggestions of what these could be used to assess.

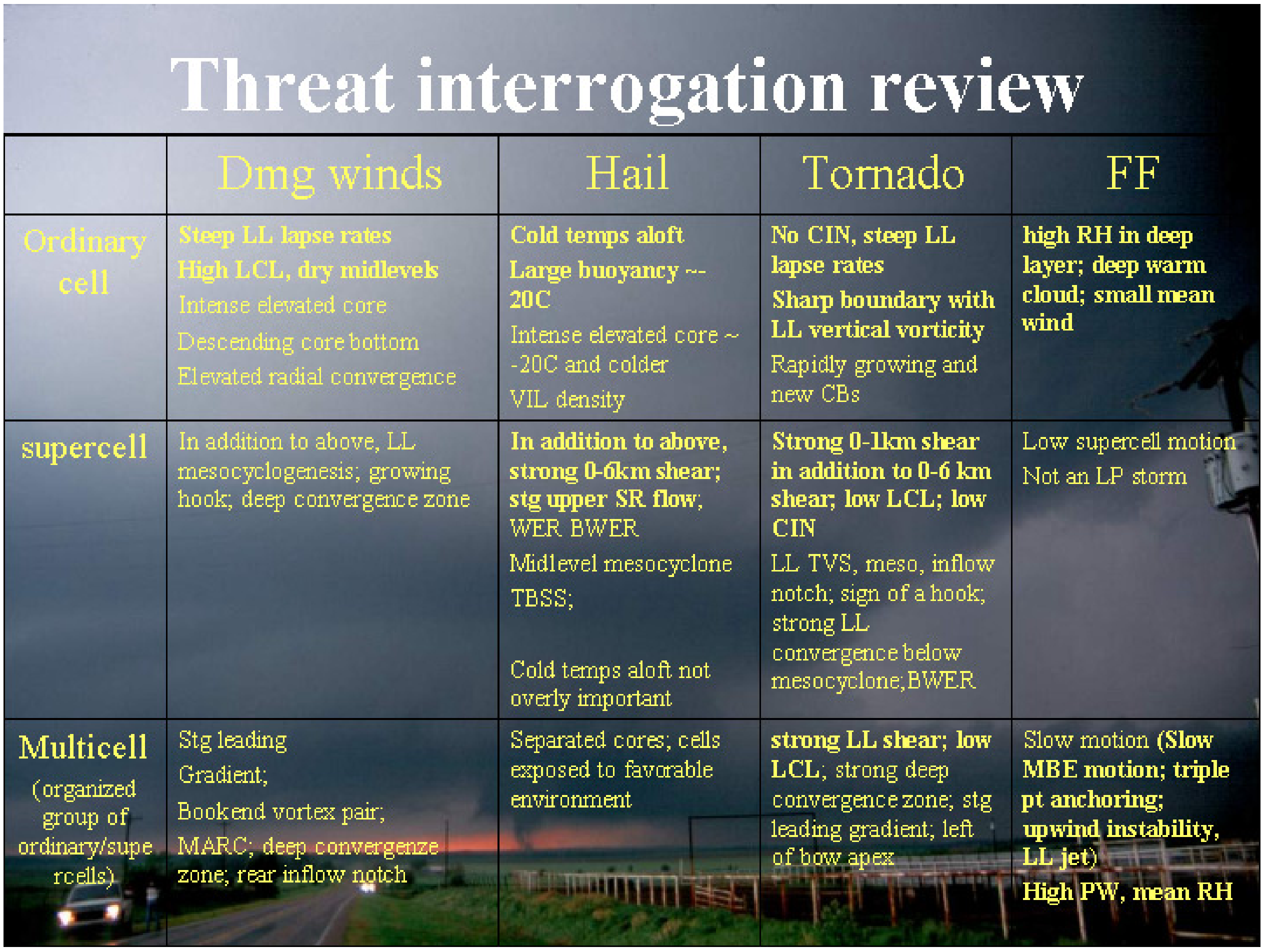


Back to my example here with my mesoanalysis display, I'm looking at the splitting storm (viewed by GOES-8 visible in the center). And I have temp, dewpoint, wind from LAPS and I compare them to the metars. I notice that the LAPS analysis shows a ridge of moisture to the east of the storm. The storm is moving southeast and toward the ridge of moisture. The winds are not very high but I also notice that the storm is riding on a cold front and the cold front is marked by the red line. If the storm can stay on the cold front...and I notice that the cold front has cold air behind. Looking at the skewt the post-cold front air is too stable for surface-based convection. So I need this storm to stay on the front or ahead of it for tornado potential. I believe it will because the storm is moving southeast at least as fast as the front. So that's a good sign. There's weak shear at low-levels but there's strong 0-6km shear, the LCLs are low and there's superb amounts of convective instability (5000 j/kg cape).



Okay, we've screeened the storms, then investigated the storm with the highest tornadic potential, then we've looked at all that data in context of the mesoscale environment. We found the environment kind of supports that if I see a supercell, it could produce a tornado. Now I'm going to consider the warning. I'm going to go ahead and load up my warngen on top of a base reflectivity and SRM loop. However, you could also have 8 bit Z/V as well, and load that up as a procedure, load it up and there you have it. The 8 bit has much better resolution and could provide you with that last piece of evidence that will help you in your decision making process.

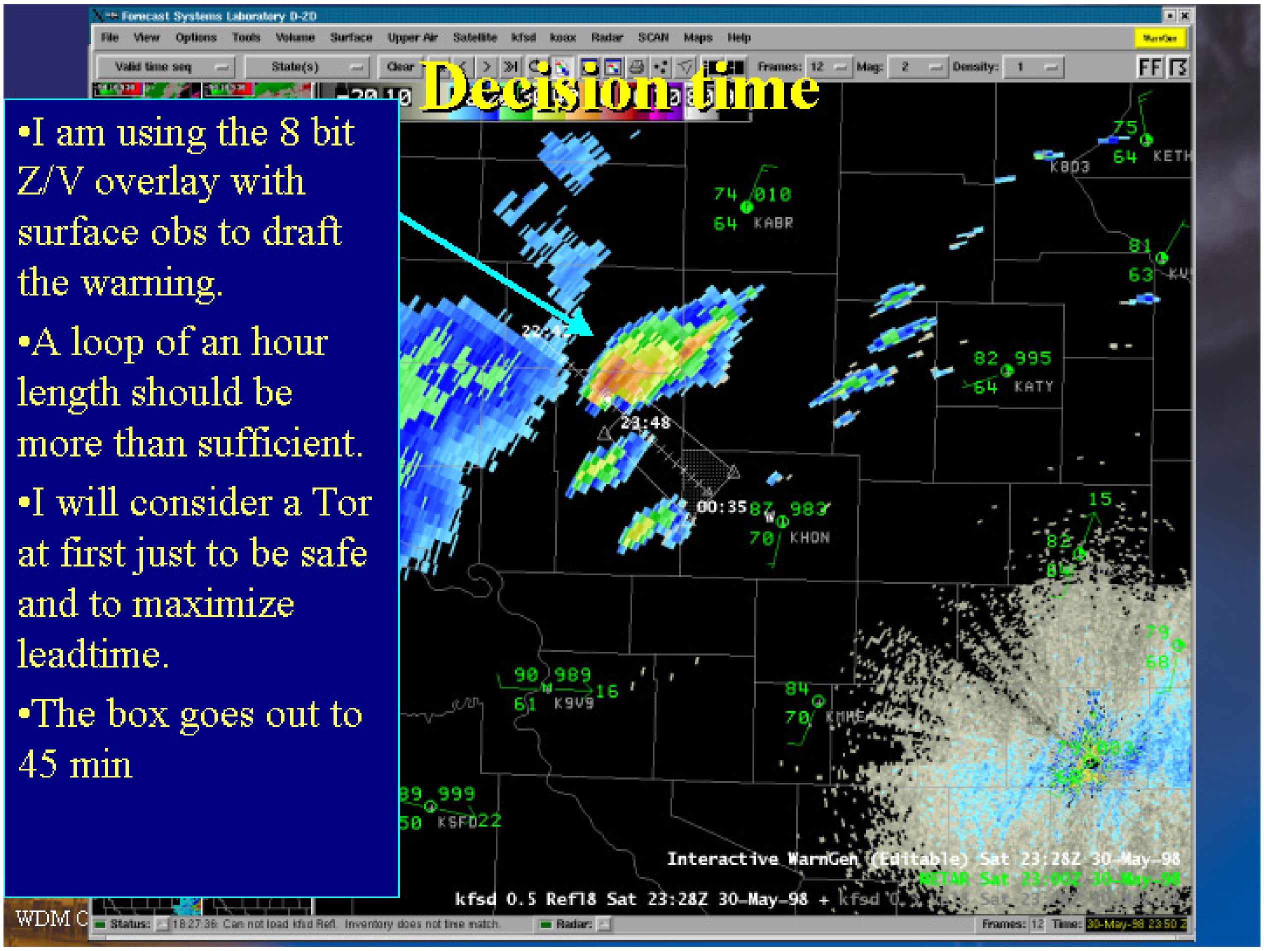
We'll compose the warning and do a sanity check. Does this storm have the required ingredients for a tornado? Does this storm have history? If there was a report, that's a big thing, a real big thing. If it doesn't then you rely on what you've got. That is, the environment, and the storm structure.



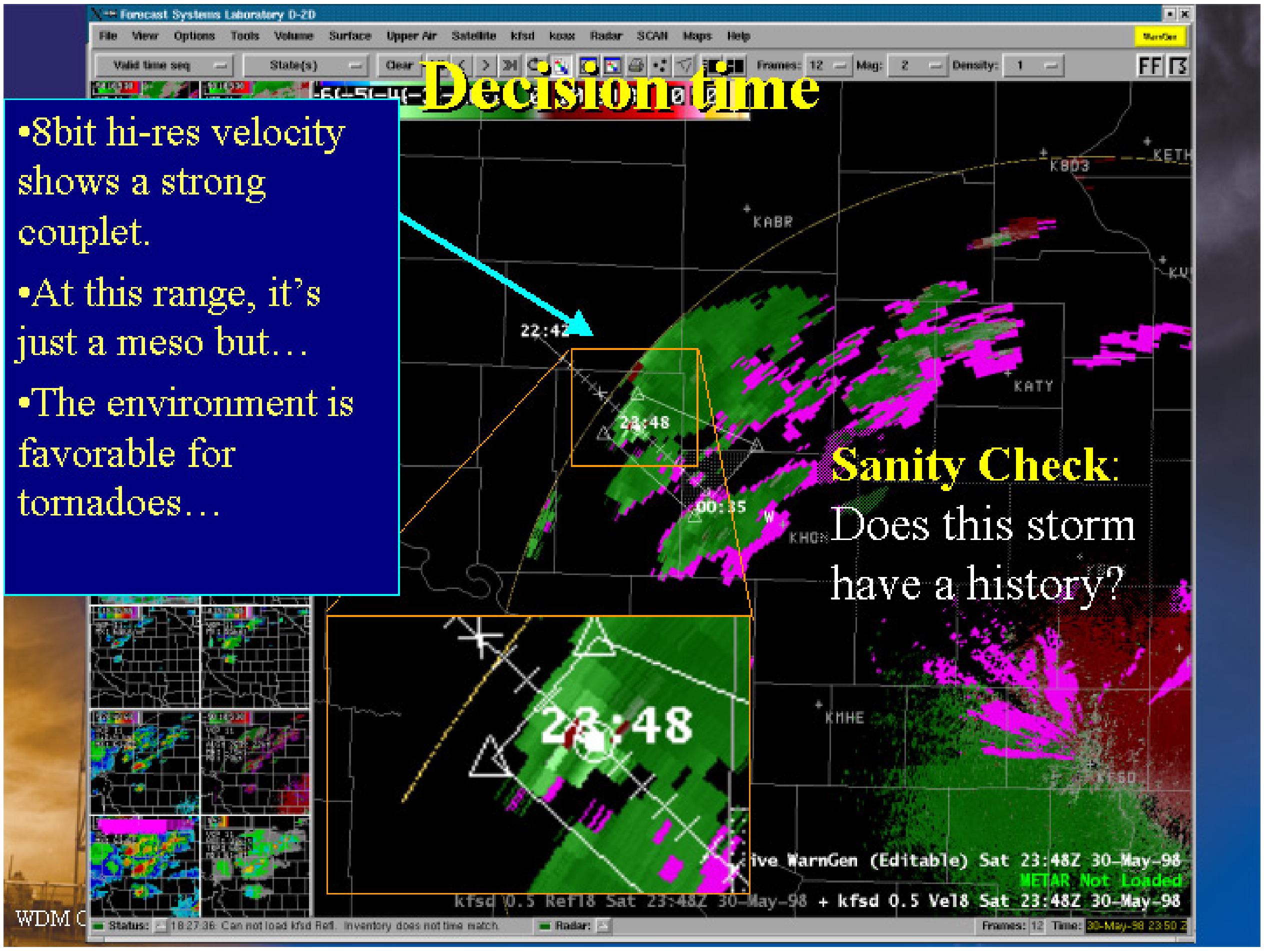
Threat interrogation review

	Dmg winds	Hail	Tornado	FF
Ordinary cell	**Steep LL lapse rates** **High LCL, dry midlevels** Intense elevated core Descending core bottom Elevated radial convergence	**Cold temps aloft** **Large buoyancy ~-20C** Intense elevated core ~ -20C and colder VIL density	**No CIN, steep LL lapse rates** **Sharp boundary with LL vertical vorticity** Rapidly growing and new CBs	**high RH in deep layer; deep warm cloud; small mean wind**
supercell	In addition to above, LL mesocyclogenesis; growing hook; deep convergence zone	**In addition to above, strong 0-6km shear; stg upper SR flow;** WER BWER Midlevel mesocyclone TBSS; Cold temps aloft not overly important	**Strong 0-1km shear in addition to 0-6 km shear; low LCL; low CIN** LL TVS, meso, inflow notch; sign of a hook; strong LL convergence below mesocyclone;BWER	Low supercell motion Not an LP storm
Multicell (organized group of ordinary/supercells)	Stg leading Gradient; Bookend vortex pair; MARC; deep convergenze zone; rear inflow notch	Separated cores; cells exposed to favorable environment	**strong LL shear; low LCL**; strong deep convergence zone; stg leading gradient; left of bow apex	Slow motion (**Slow MBE motion; triple pt anchoring; upwind instability, LL jet)** **High PW, mean RH**

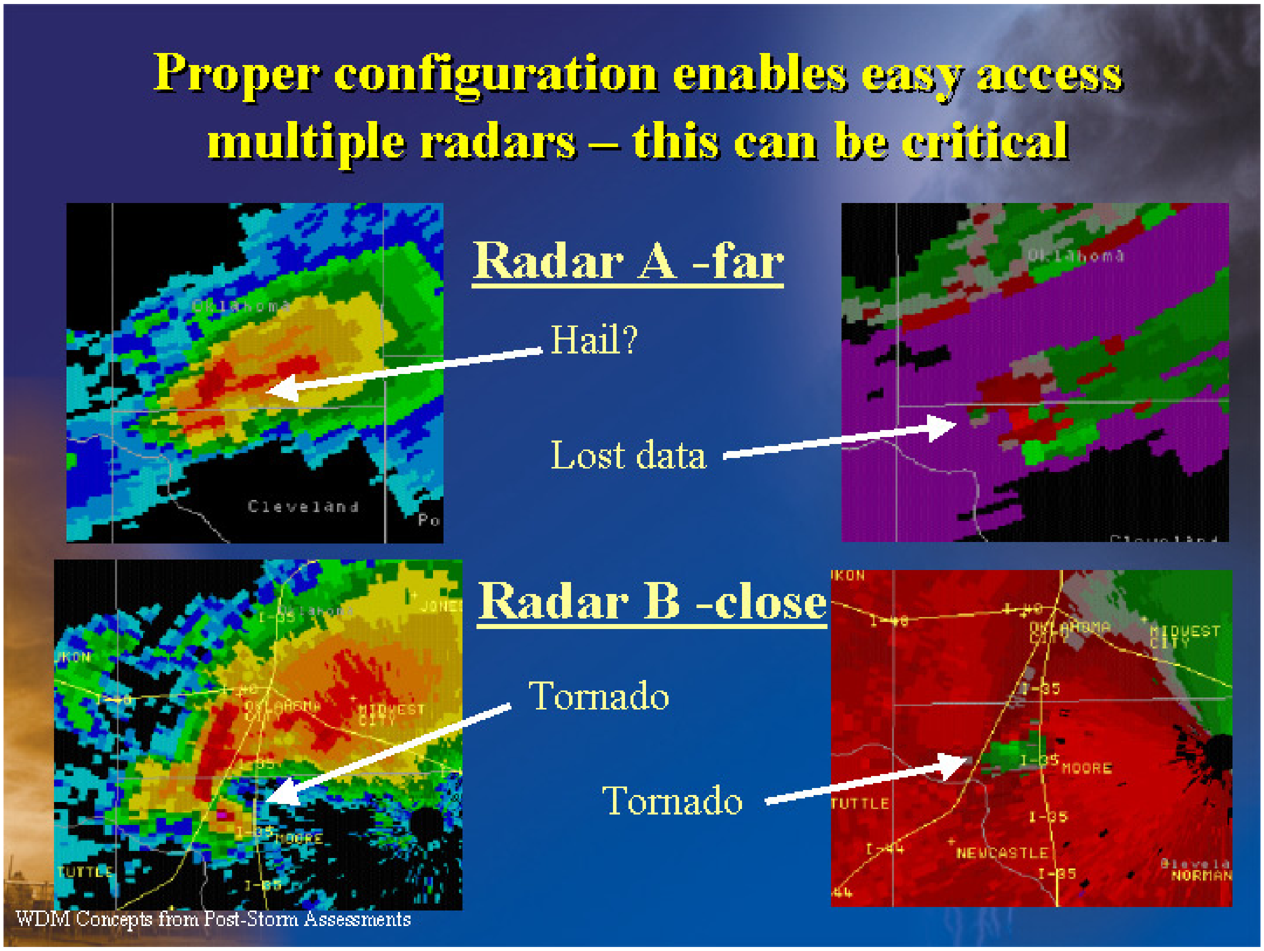
Speaking of the second frame of this loop (not to go through in detail), I have a lot of short little tips for different storms and different types of severe weather threats. Take a look at that on your off-time in case you need a refresher.



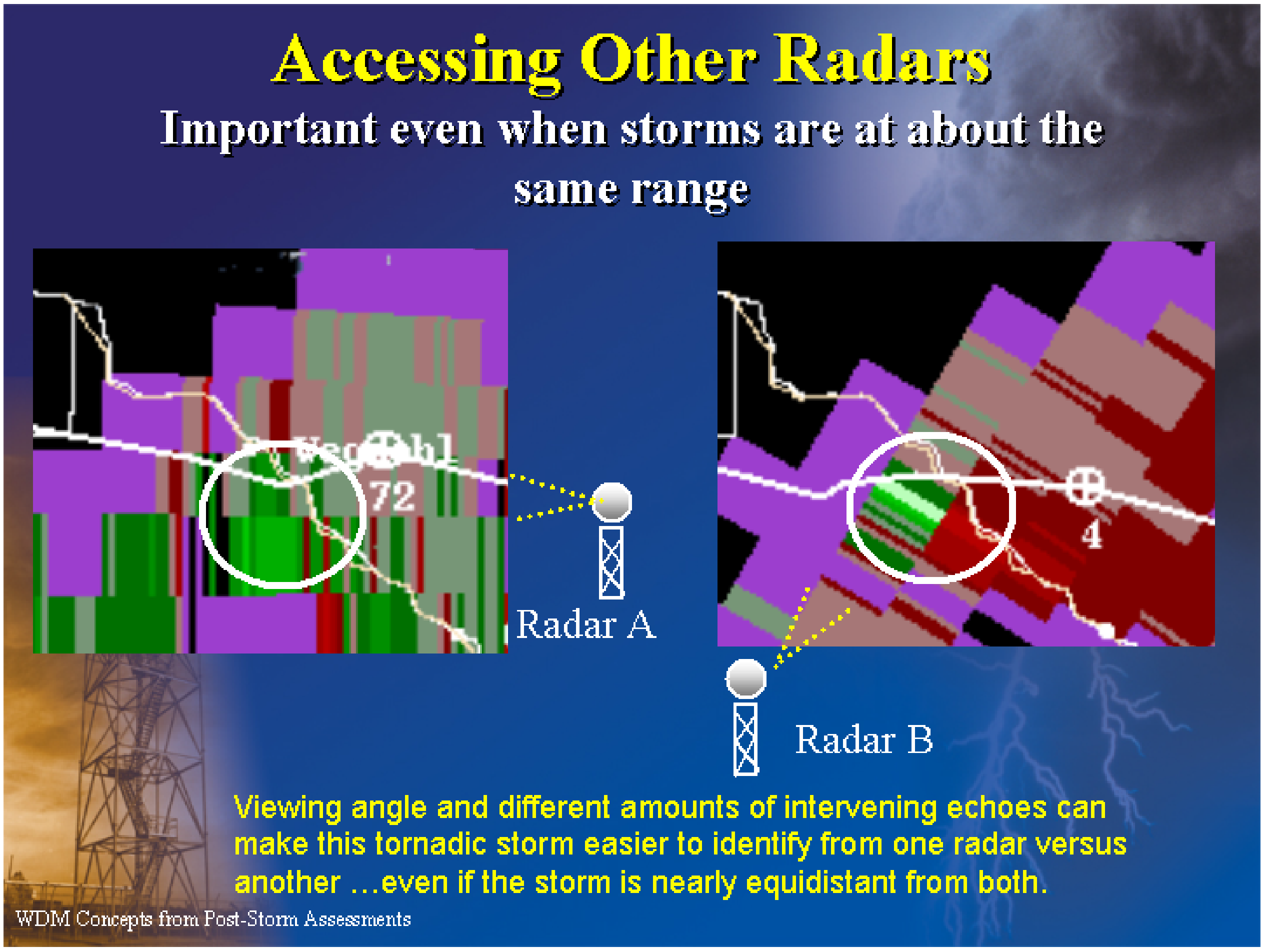
So I decided to use the 8bit reflectivity to compose my warning. And here's my decision time. I have the last 30 min loop where the storm is moving to the southeast. I redid the warning box as shown. I'm going to go ahead and use the 8 bit, especially the velocity on frame 2 to get the highest resolution.



I'm going to go ahead and consider the tornado warning and look at the second frame which is the velocity. If the storm has a history, I'll consider the history heavily, especially at this distance because of the distance to the radar. However, I lucked out with my sampling. My beams picked the inbound and outbound just right since I have a strong velocity couplet. This isn't a small-scale TVS, it's just a good, well sampled mesocyclone. We got a favorable environment, I think I'm going TOR. I extended the box to the left because I'm not sure how far this storm is going to keep right-turning. It could go off to the left, especially the individual mesocyclone as it occludes and hooks to the left.

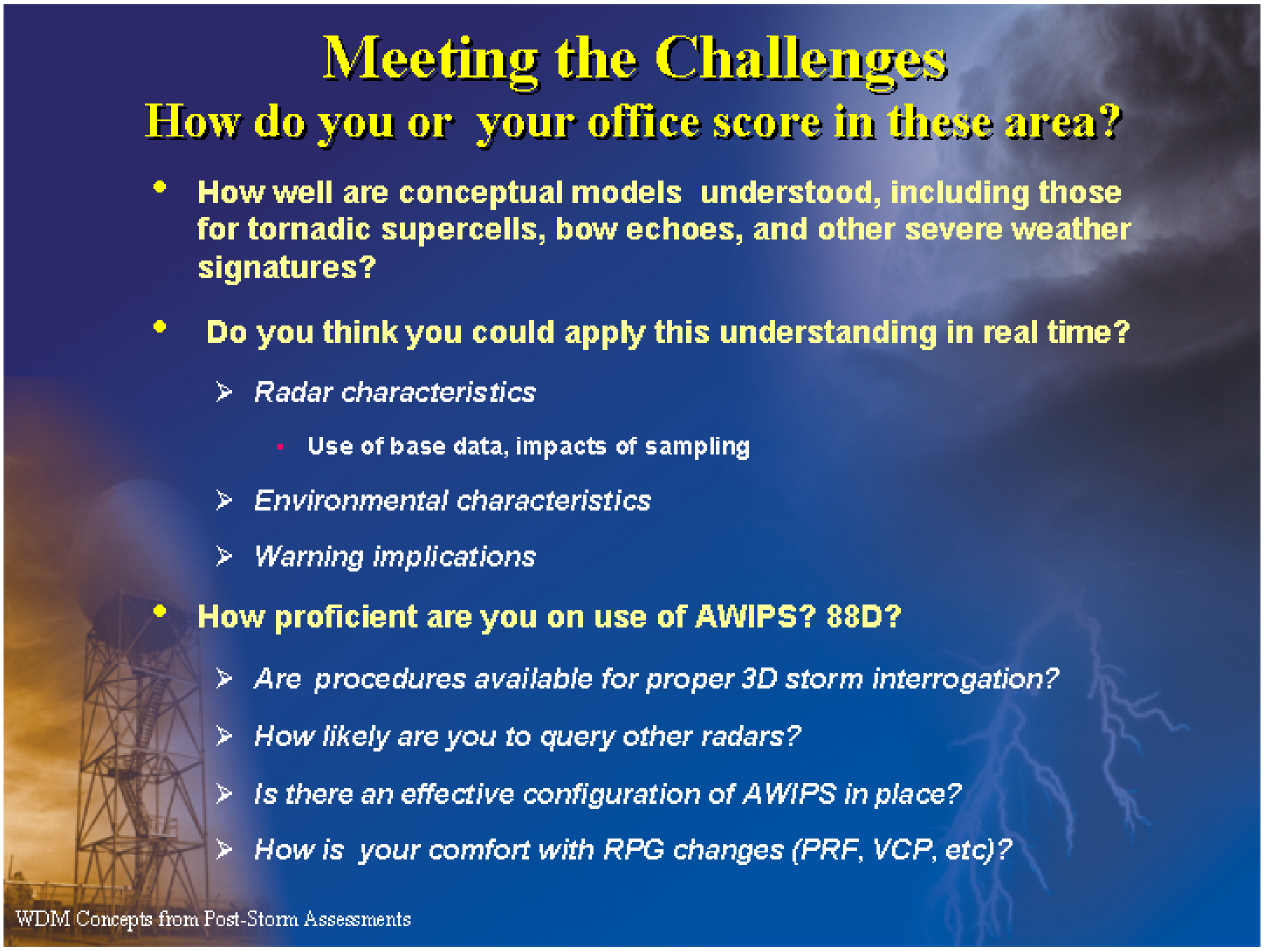


I didn't mention in step two of investigating storm structure, that you should be viewing as many radars as possible. This is a previous example that Liz showed of a debris ball from the nearby radar and that was a definite indication of a strong tornado. What happens if you were just looking at this radar (far radar). Very poor sampling with range folding here and problems like that. You lose the velocity characteristics. The long-distance radar reflectivity doesn't show very much structure compared to the bottom nearby radar. You can imagine how your warning decision might change if you only looked at radar-A.

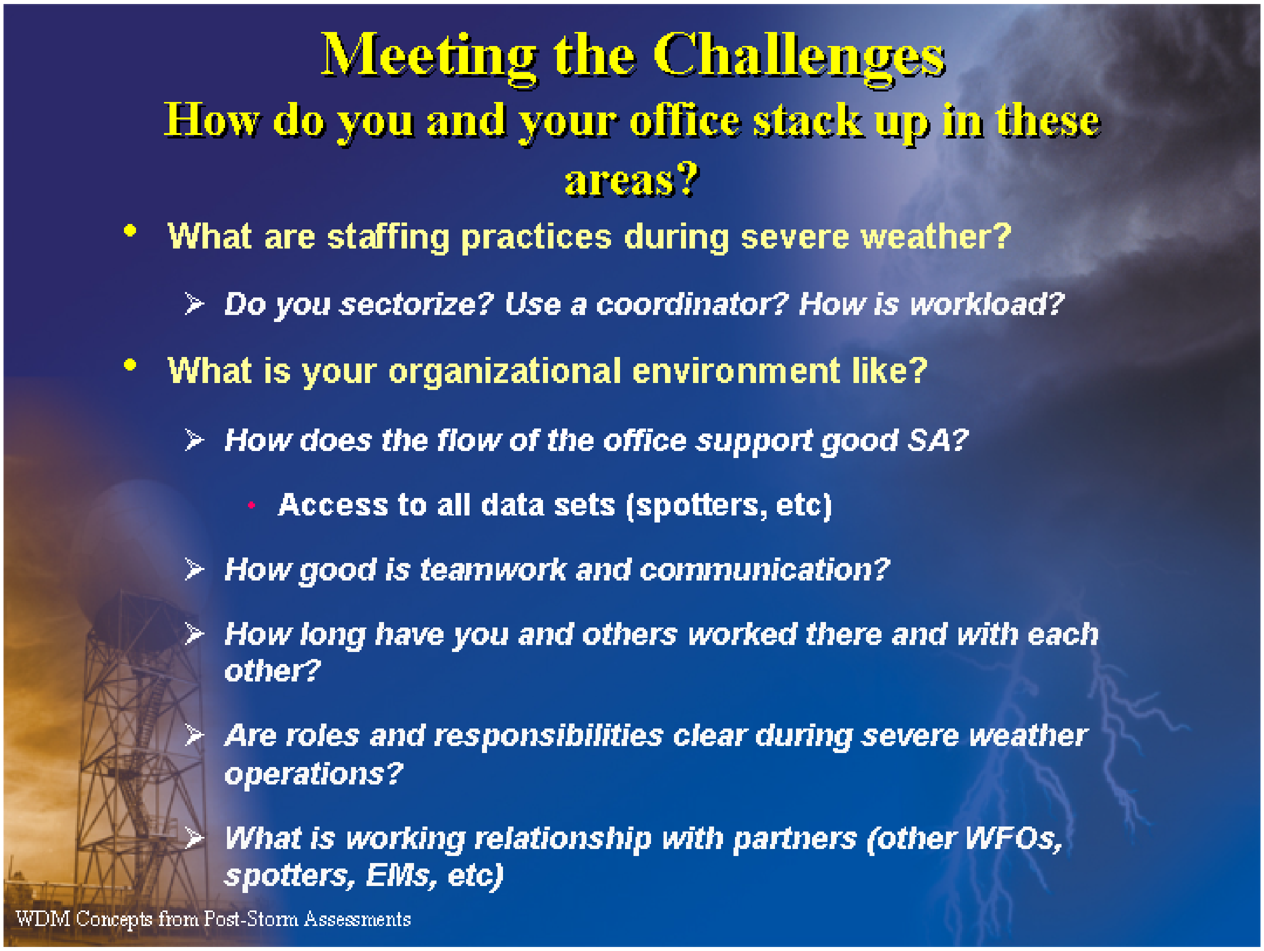


It's also important that even if you don't have a close-by radar. What happens if you have two radars at the same range but at different vantage points? It's still important to take a look at both radars because it just so happens that the mesocyclone might be sampled differently between those two radars. This is a great example here. Radar-A off to the east 130km away shows a weak circulation feature, a bare suggestion of something going on. Radar-B off to the southwest the same distance suddenly shows a very strong velocity couplet. It may be because Radar B's beams better sampled the in- and outbounds of the mesocyclone.

This example is from the Granite Falls, MN tornado back in July of 2000. Radar A was from Minneapolis and Radar B is from Sioux Falls. If you were just looking at Radar B, your warning decision might be different than if you viewed the storm from only Radar A.

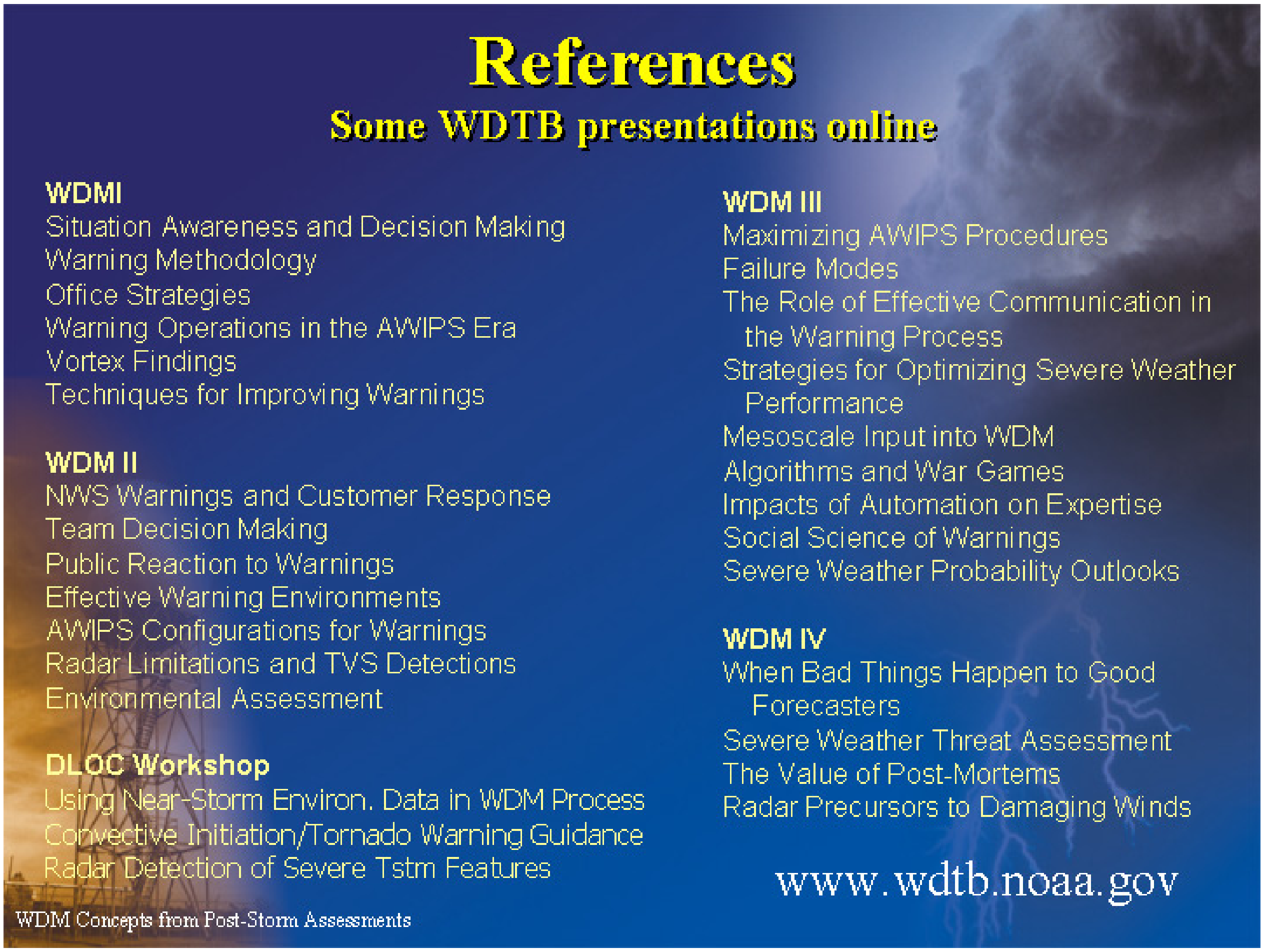


So, as we are kind of winding down here, maybe you can think about these questions that we have raised and that these assessments have raised and how ready are you to meet the challenges, how do you or your office, or your co-workers, your organization score in these areas. These things that came up in these assessments, how well are you at understanding conceptual models, for whatever types of features that you get routinely and those you get every now and again, because those may be as much a challenge as what you get routinely. Do you think you can apply this in real time, do you understand the radar characteristic, the environmental characteristics. Do you know what that means you should do with warnings when you have a cyclic tornado supercell, for instance. How proficient are you in using AWIPS, do you have procedures available, do you have easy access to other radars that you routinely make use of. Is there an effective configuration of AWIPS in place, one that doesn't drain your efforts in trying to get the right maps and the right thickness of lines and colors. How is your comfort with making changes at the RPG - PRF and VCP changes, for instance.

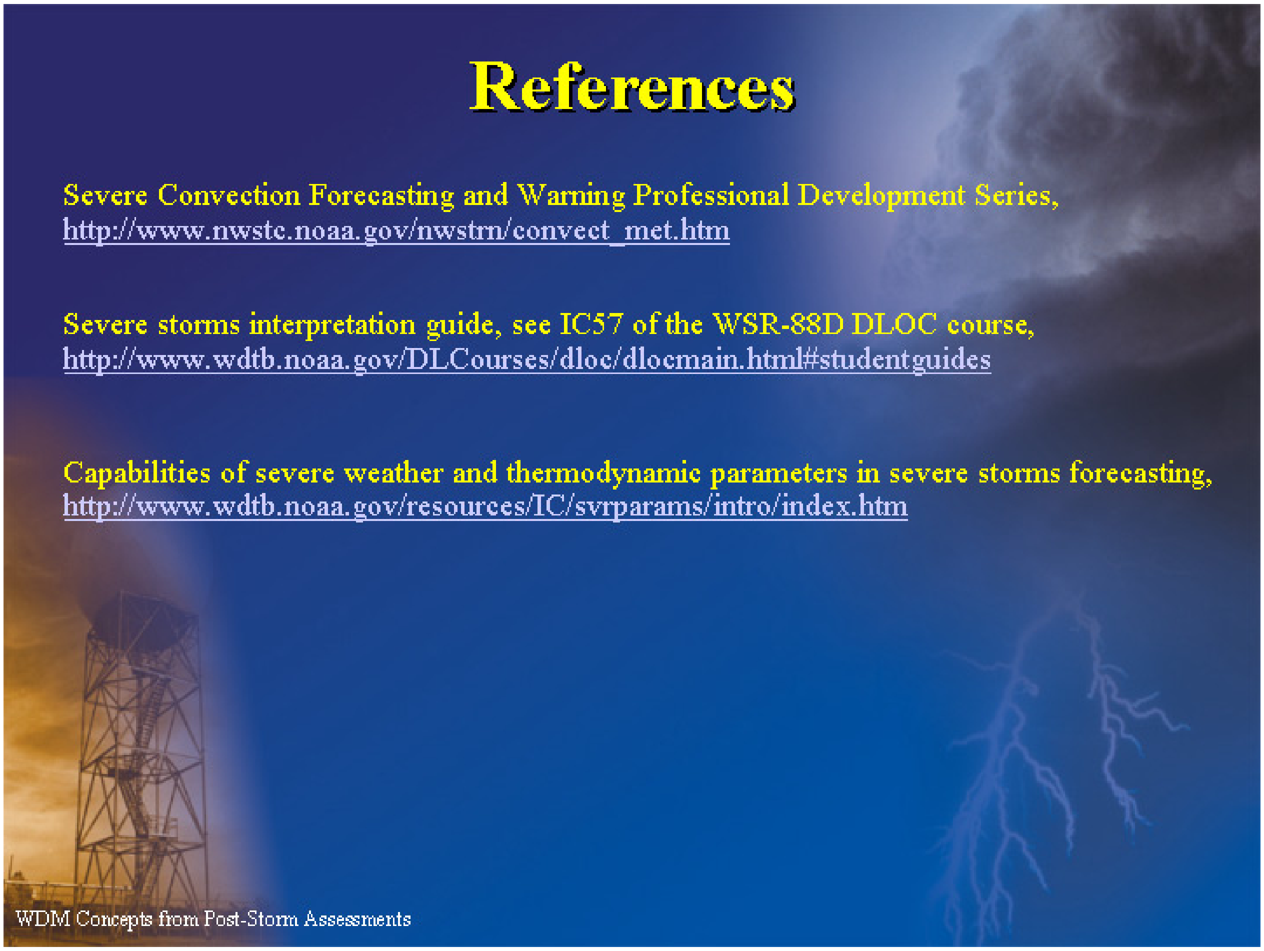


Some other questions you might ask yourself are what are the staffing practices during severe weather. Do you sectorize routinely, do you use a coordinator, how is the workload, is it distributed equally amongst the staff, does everybody understand what they are doing with that. Are you able to adjust it if things seem a little more intense that you anticipated. The organizational environment, does the office support good situation awareness, in other words, do you access to all data sets and shared information easily. Do you have perhaps a situation display which gives everybody the same common type of information that they need to know. Teamwork and communication, very important. How do you work as a team and how do you communicate, especially when you have turnover and you have new staff or folks that don't have a lot of experience. You can use the Weather Event Simulator to work on theses skills, put teams together that perhaps will be working together more often and get them a chance to get to know each other in that environment. Does everybody know what he or she are supposed to do and know that perhaps this is my job right now but might evolve into something else later. Do people speak up whenever they sense that they need to modify their responsibility. And what is the working relationship or the ground work that you've done with your partners, other FO's, spotters, other emergency managers, etc.

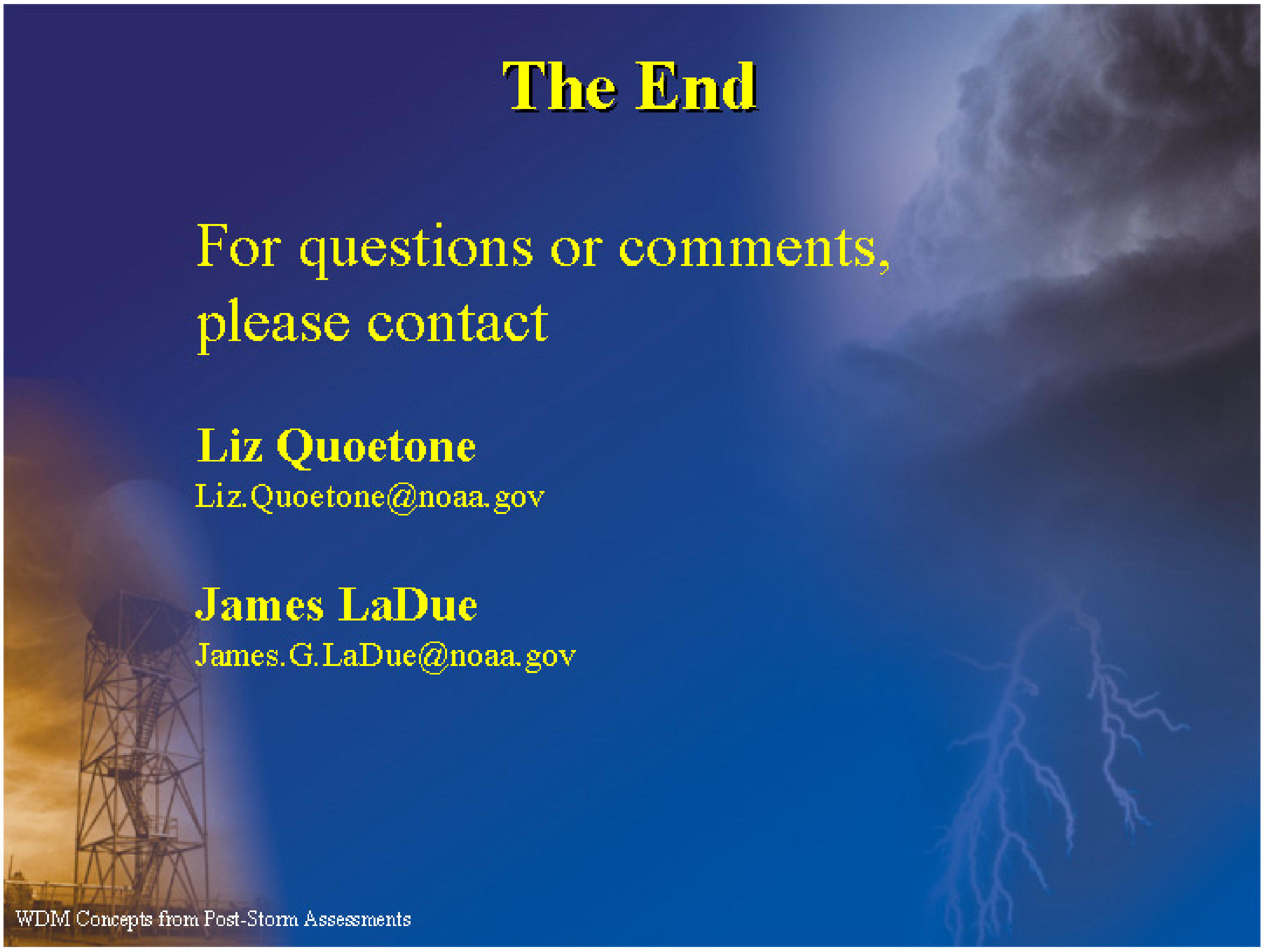
We've provided several references for you for material that was presented in this session, lots of them, if you choose, you can look up on the Internet or there are other sources for you to do that.



Many of the talks that have been presented at Warning Decision Making Workshops over the last several years are available on line at the WDTB web site and we have used a lot of information from those talks as a summary into portions of this presentation as well. Most of them are either downloadable or displayable on the web site.



And a few more references from the professional development series on Convective Forecasting that you can also access on the web site are available for you.



And finally, if you have any questions or comments, please feel free to contact myself or Jim LaDue and there's our email addresses. We appreciate you taking the time out of your busy day to go through this session and please give us any input and we look forward to working with you in the future. Thanks everybody!